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Female Persistence in Science: Exploring the Achievement Motivation and Epistemological Characteristics of Post-Secondary Students

By

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ABSTRACT

The purpose of this study was to explore factors underlying a well-documented tendency of female students to not pursue advanced courses and or careers in the Sciences, though they maybe as capable as male students in these disciplines. This question of persistence in Science was examined by 1) defining two elements of persistence in a post-secondary student population (i.e., student interests in Science and student commitment to a Science major) and 2) examining, in relation to these elements, individual and gender differences within four models: Eccles' (Eccles et al., 1983; Eccles 1987) Model of Achievement Motivation, Schommer's (1990; 1994) Epistemological Beliefs, Belenky et al.'s (1986) Women's Ways of Knowing, and Waterman's (1982) Science Epistemology.

This study employed a series of MANOVAS and Logistical Regressions on questionnaire data obtained from one hundred and fifty-one participants drawn from three sources: two Western Canadian post-secondary institutions, and a pool of graduates from the Shad Valley program, a university-based summer program for high school students excelling in Science. The graduates currently attend post-secondary institutions across Canada. In addition to the questionnaire data, twenty six participants (16 females and 10 males) were randomly drawn from the Shad Valley sample group and interviewed to obtain their approaches to knowing and their views of the nature of Science knowledge.

The findings of this study expanded upon the literatures supporting the models under-study, and they contributed further to the literature exploring female persistence in Science. Eccles' (Eccles et al., 1983) model, which is primarily based upon studies involving secondary students, successfully predicted individual and gender-related differences in undergraduate student interests in, and commitments to, a Science. Schommer's (1990; 1994) beliefs about knowledge and learning, which are known to affect student learning, were shown in the present study to be directly associated with elements of persistence (e.g., committing to a major in a Science). Previous research on Belenky et al.'s (Belenky et al., 1986) separate and connected knowing confirmed their association with gender and several cognitive constructs (e.g., differentiation). In the present study, these constructs were found to have a gender-related association with persistence. That is, female students, but not their male counterparts, appear to experience a shift from connected to separate approaches to knowing when committing to a major in Science. Finally, the present findings indicated there is a general set of changes in epistemology and values experienced by female students and not by their male counterparts. Female students increase their beliefs in a fixed ability to learn, in the simple, fact-like nature of knowledge, and in the utility of their courses, when they commit to a major in a Science, though the levels their endorsements remained lower than those of male Science majors. The impact of these changes in epistemology, values, and the shift in approaches to knowing have not been previously identified as factors influencing female persistence in Science, and they suggest a promising area for further research.

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CHAPTER I

Introduction

> It is hard to find a more controversial topic in recent behavioural and social science research than that of gender differences in achievement. During the last 30 years or so, a great deal of research has been devoted to explaining these differences (Rogers, 1991, p. 193).

By the mid-1920s, women were acquiring doctoral degrees in the field of Science, though they were few in number and largely absent from Science faculties. This continued to be the case through the 1930s and 1940s. Moreover, in the 1950s, there was a significant drop in the number of women acquiring doctorates and positions in Science faculties (Morse, 1995). Ten years later, the developing feminist literature extended its critiques to the scientific disciplines, and this prompted an interest in exploring the underrepresentation of women in Science (Adams, 1996; Rosser, 1990). In the 1980s, this interest was given additional impetus by several national reports (e.g., a 1982 National Science Foundation report on Science and Engineering education) that predicted a significant shortfall in scientists in the 1990s (Rosser, 1990). Although there has been a greater interest in and research on the issue of underrepresentation of females in Science disciplines in the last decade, the problem still remains. Currently, women comprise 8% of the total of employed engineers, 36% of mathematical and computer scientists, and 27% of chemists (White, 1992).

Researchers exploring gender and Science have examined a broad range of constructs in their efforts to understand why young women tend not to pursue advanced education and careers in the Sciences (i.e., Physics, Chemistry, Math, and Engineering). Previous researchers have identified numerous constructs including values (e.g., Linn & Hyde, 1989; Kerr, 1994; Steinberg & Gwizdala, 1995), self-confidence (American Association of University Women, 1991; Zorman, 1996), perceptions of ability (e.g., Adams, 1996; Zorman, 1996) and attributions (e.g., Eccles, Jacobs, & Harold, 1990), all of which have been shown to have a significant effect on women's achievement in the area of Science. In addition, such social factors as classroom biases (e.g., Ware, 1985; Rosser & Potter, 1990; Sadker & Sadker, 1994), stereotypes of Math and Science as masculine domains (e.g., Hollinger, 1991b; Hyde, Fennema, & Lamon, 1990; Noble, 1989), and peer and parental influences (e.g., Callahan, Cunningham, & Plucker, 1994; Eccles, Jacobs, & Harold, 1990; Kramer, 1991;) have been found to operate singularly, and in conjunction with individual constructs, to influence women's achievement and achievement-related decisions in the Sciences.

One model which successfully brings together a number of constructs and social factors to predict gender-related patterns in achievement-related decisions (i.e., choice of courses and careers) is Eccles et al.'s (1983; Eccles, 1987; hereafter described as Eccles') Model of Achievement Motivation. According to this model, an individual's educational or occupational choice is guided by his or her expectations for success on and the subjective (i.e., intrinsic, utility) values assigned to available achievement options. These beliefs, in turn, are affected by such factors as perceptions of task difficulty associated with each achievement option, personal goals, self-concept and self-perceptions, aptitudes, and interpretations of past experiences. The model suggests these beliefs and factors are shaped by an individual's perceptions of cultural norms and of socializers' (e.g., parents, teachers) beliefs and behaviours.

Although the body of research supporting Eccles' model (Eccles et al., 1983; Eccles, 1987) is extensive, there are two avenues that have not been explored and that might contribute to our understanding of persistence in the Sciences (i.e., why women tend to pursue advanced education and careers in fields other than Science, though they are as capable as their male counterparts in these disciplines). Research on this model has focused on confirming its ability to predict gender differences in secondary students' course selections and the occupational choices of adults. However, the model has not been explored in relation to undergraduate students and the question of persistence in Science. This student population is of particular interest when considering the question of persistence, as it is during the undergraduate years that students make critical decisions about pursing education in a particular discipline. They have an opportunity to explore and follow their interests (whether intrinsic, utilitarian, or both), and they must commit to a major in a specific discipline. Thus, exploring this population allows for the possibility of examining these two circumstances as elements of persistence (i.e., academic interests, as reflected in favourite subjects, and commitment to a major, an act reflective of persistence). Moreover, exploring the relationships among gender, Eccles' constructs, and these elements of persistence would permit addressing such questions as: Does

Eccles' model predict elements of persistence (i.e., student interests in, and commitment to, a major) given its ability to predict student course selection? Does the model identify gender differences in student interests in, and commitments to, a major? Exploring these questions in a student population making critical academic and career decisions may further our understanding of female persistence in Science.

A second avenue not explored in the literature on Eccles' (Eccles et al., 1983; Eccles, 1987) model is examining this model in relation to models that influence student performance. One such model is Schommer's (1990; 1994) Epistemological Beliefs. This model articulates a set of epistemological beliefs defined as a continuum and characterized as relatively independent components of a system of personal epistemology. Specifically, the model entails four beliefs: *Fixed Ability*, which ranges from the belief that the ability to learn is fixed at birth to the belief that the ability to learn can be improved over time; *Quick Learning*, which ranges from the belief that learning occurs in a short amount of time, or not at all, to a belief that learning is gradual; *Certain Knowledge*, which ranges from the belief that knowledge is certain and absolute to the belief that knowledge is tentative and contextual; and *Simple Knowledge,* which ranges from the belief that knowledge is best thought of as isolated facts to the belief that knowledge is characterized as complex, interrelated ideas.

The literature supporting this model of epistemology indicates these beliefs have a subtle but critical impact on learning (Schommer & Donnell, 1994). For example, these beliefs have been shown to predict GPA, performance on class tests, and confidence in (as well as monitoring of) text comprehension (Schommer, 1988; Schommer, 1990).

Although this body of literature is comprehensive and growing, Schommer's (Schommer, 1990; 1994) model has not been examined in relation to other models affecting student achievement, particularly achievement-related decisions. Examining relations between this model and that of Eccles (Eccles et al., 1983; Eccles, 1987) may allow for a richer description of the influences of both models on students, particularly with respect to persistence in the Sciences. For example, is there a relationship between constructs that affect student decisions (i.e., Eccles' constructs) and constructs that affect student performance (i.e., epistemological beliefs)? Do these two sets of constructs (i.e., models) either individually, or in combination, influence elements of persistence (i.e., student interests and commitment to a major)? Are there individual and/or gender differences in the relative importance of the models' constructs when considering each element of persistence? Exploring these questions may provide a better understanding of the factors affecting student learning and student persistence in Science.

A second model of epistemology affecting student learning and that may contribute to our understanding of female persistence in Science is Belenky et al.'s (1986; 1997) Women's Ways of Knowing (WWK). This model describes five perspectives of knowledge that "capture some of the major ways women... think about themselves, authorities, truth, and life options" (Goldberger, Tarule, Clinchy, & Belenky, 1996, p. 4). The perspectives are (as detailed in Goldberger et al., 1996): 1) *Silence*, a position in which an individual feels they are unable to generate knowledge; 2) *Received Knowing*, a perspective in which knowledge is viewed as external to the individual; 3)

Subjective Knowing, a position in which knowledge is viewed as personal and based on intuition rather than on ideas defended with evidence; 4) *Procedural Knowing*, a perspective in which processes for generating and validating claims of knowledge are developed and valued. This position subsumes two approaches to knowledge: a) *Separate Knowing*, which entails a distant, skeptical, and impartial stance towards the object the individual is attempting to know, and b) *Connected knowing*, a stance of belief and an entering into the place of the other person or idea that one is trying to know; and *Constructed Knowing*, a position in which knowledge is viewed as contextual, tentative, and constructed by the knower.

In their original work, Belenky et al. (1986) found that a mismatch between student and post-secondary course approaches to knowing had a significant negative effect on female students. Specifically, female students with a 'connected' approach to knowing who were exposed to 'separate' pedagogical practices reported feeling disconnected and distant from 'separate' knowledge and the knowledge enterprise. The authors noted that "connected knowers struggle with understanding and developing a 'separate' Way of Knowing, and in their attempts to do so, end up suppressing the self and feel that they were not making themselves heard" (Belenky et al., p.199-200). Occasionally, the authors noted, "this tension prompts them to leave courses and/or university because their only tool for knowing has been challenged and taken away" (Belenky et al., p. 202). These findings suggest female students with a 'connected' way of knowing experience significant tension when exposed to 'separate' pedagogy. How do female students resolve this epistemological tension when pursuing Science, a discipline noted for its 'separate' approach to pedagogy (Bendixen, Dunkle, & Schraw, 1994)? Do they adopt a 'separate' approach to knowing? Does this adoption extend to their personal lives, as well as to their academic lives? Exploring how this epistemological tension is resolved may provide a greater understanding of the factors influencing female persistence in Science.

A second epistemological mismatch may occur when Science students hold conceptions of Science knowledge which differ markedly from those held by their instructors and the Science curriculum. The literature exploring Science epistemology indicates secondary and post-secondary students generally hold theories and conceptions of Science that are 'traditional' or empiricist in nature (e.g., Grosslight, Unger, & Jay, 1991; Ryan & Aikenhead, 1995; Waterman, 1982) despite recent efforts by Science instructors (and Science curriculum) to promote a 'constructivist' approach to Science (Carey & Smith, 1993; Edmonson & Novak, 1993). Such a mismatch has been shown to negatively affect the teaching-learning process for both male and female students (Goldberger, Tarule, Clinchy, & Belenky, 1996; Schon, 1987; Tobin, Tippins, & Hook, 1995). Does this mismatch affect persistence in Science? Might it create a second epistemological tension that, in concert with the tension described by Belenky et al. (1986), negatively affects the willingness of female students to persist in Science?

One model of Science epistemology that appears to have a direct relationship with Belenky et al.'s (1986) Women's Ways of Knowing is Waterman's (1982) Model of Science Epistemology. This model articulates three distinct views of Science knowledge: The *Traditional* view depicts Science knowledge as discovered and based on absolute, observable facts, as well as additive, rather than tentative in nature. The *Modified-Traditional* view suggests that although Science knowledge is discovered and based on observable facts, it remains tentative and changeable due to the limitations of the scientific method and/or human senses. The *Contemporary* view portrays Science knowledge as products of the human mind (i.e., constructed rather than discovered), and as being probabilistic, rather than absolute, in nature. These conceptions of Science epistemology are consistent with those used by many current researchers exploring the role of Science epistemology in learning Science (e.g. Carey & Smith, 1993; Hammer, 1994). As well, the 'Traditional' and 'Modified-traditional' views appear to be consistent with a 'separate' Way of Knowing. Specifically, Waterman describes the Scientific Method as the operational basis of the 'Traditional' and 'Modified-traditional' views of Science. Belenky et al. (1986), as well as Clinchy (1989a; 1989b; 1996), have described the Scientific Method as the primary tool of 'separate' knowing. Given this commonality, a relationship between approaches to knowing and conceptions of Science knowledge (i.e., Science Epistemology) is suggested. Does this posited relationship, as well as the evidence of mismatches in Science Epistemology noted above, indicate a second source of epistemological tension that, acting conjointly with the tension identified by Belenky et al. (1986), negatively affects female persistence in Science? Neither the posited relationship, nor its implications, have been explored, empirically.

The present study explores the above issues and the question of female persistence in the Sciences by examining, across two elements of persistence (i.e., favourite subject, commitment to a major), individual and gender differences in the relationships between Eccles' (Eccles et al., 1983) Model of Achievement Motivation and Schommer's (1990; 1994) Epistemological Beliefs. In addition, as a preliminary step to examining the affect of epistemological tensions on female persistence in the Sciences, the present study will explore the relationships between approaches to knowing, Science Epistemology, and female student commitment to a Science major.

The next chapter (Chapter II) provides the reader with summaries of the research supporting the models under investigation. Particular attention will be paid to research relating to the questions of this study.

Chapter III describes the research methods, including participant selection, data collection procedures and instruments, as well as the procedures for the analyses of the research questions. Chapter IV presents the results of the data analyses, and Chapter V discusses these results in light of the literature reviewed in Chapter II. Chapter V also includes a discussion of the limitations of the current study and future directions for research on female persistence in Science.

CHAPTER II

Literature Review

This chapter provides a brief summary of the background literature relating to female persistence in the Sciences. This is followed by chapter sections summarizing research supporting Eccles' Model of Achievement Motivation and three models of Epistemology, including Schommer's (1990; 1994) Epistemological Beliefs, Belenky et al.'s (1986) Women's Ways of Knowing, and Waterman's (1982) Science Epistemology. The chapter ends with a summary of the research presented in the chapter.

Female Persistence in the Sciences

Researchers have identified several individual constructs and social factors that affect women's achievement and their pursuit of advanced education and careers in Science. These include perceptions of ability and self-confidence, values, stereotypes, biases, and the influence of peers and family. The research exploring these constructs and factors is summarized below.

Perceptions and Confidence

A number of authors have identified perceptions of ability and self-confidence as factors affecting female achievement. Kerr (1985), as well as Buescher and Higham (1989) and Sadker and Sadker (1994), note that young girls begin to lower their estimation of their Math and Science abilities in junior and senior high school. Kline and Short (1991), in a cross-sectional study of gifted females in grades one through 12, found a progressive decrease in self-perceptions of ability and confidence. This decrease continues through the transition to college (Arnold & Denny, 1985), and decreases in confidence are evident as late as graduate school (American Association of University Women, 1991).

These changes in perceptions and confidence are particularly evident in the area of mathematics. In their research on gender differences in the field of mathematics, Meyer and Koehler (1990) found that, among high ability adolescents, self-confidence in math drops significantly for females over the course of secondary school. Terwilliger and Titus (1995) noted that even after participating in a mathematics program, female self-confidence was significantly less than that of male program participants. Junge and Dreztle (1995), in a survey of talented students, found female students had less confidence in their math abilities than did their male peers. These findings are supported in a report by the American Association of University Women (1991), which found that girls perceive themselves as having low abilities in math and that they feel a lack of confidence in math.

The decreases in perceptions of ability and confidence have been found to mitigate achievement. Zorman (1996) noted that less confidence in math leads to less participation in advanced, high school math courses. A study by Blair and Lupart (1996) directly examined female particpation (i.e., persistence) in university mathematics programs. They found that female students who withdrew from mathematics programs, versus those who persisted in these programs, had significantly lower confidence and interest in, and lower perceptions of ability in, the area of mathematics.

The connection between perception of ability and academic choices has been described in a number of studies by Eccles and her colleagues (for reviews of her work, see Eccles, 1987; 1994). They have found that self-perceptions of ability play an important role in forming expectations for success, which in turn influence educational and occupational choices. According to this model, believing one is not good at math leads to lower expectations of success and less likelihood of choosing additional, advanced courses in math. The model and its supporting literature are discussed in greater detail in the next section of this chapter.

Values

The perceived relevance (i.e., the utility value) of an academic subject has been shown to play an important role in achievement-related choices (Freidler & Tamir, 1990). In a series of studies, Eccles and her colleagues (for a review, see Eccles, 1987) have found that the perceived value of a subject and/or career plays a key role in the choice to pursue that subject or career, and that males and females assign different values to math and science (Eccles, 1984). Friedler and Tamir (1990) indicated that female students were significantly less likely to see the importance of science for society and for their own personal lives, and they were less interested in pursuing a science-related career, such as, engineering and research. Steinback and Gwizdala (1995) and Linn and Hyde (1989) found that boys, more than girls, ranked mathematics as useful and important to their careers, and that perceived usefulness was a significant factor influencing persistence in math and science. Given the gender difference in the perceived utility value assigned to math and science, it is not surprising females are less likely to choose advanced math courses and/or a math-related career.

A number of authors have identified conflicts in values during adolescent female identity development as a factor in female achievement. Yewchuk (1992), among others, noted that during adolescence conflicts arise between a female's identity as high achieving and her emerging identity as a woman. The particular values thought to be in conflict include: achievement versus affiliation, achievement versus relational needs, achievement versus acceptance (Bell, 1989; Luther, Ziegler, & Goldstein, 1992; Noble, 1989; Reis, 1987), and achievement versus conformity (Kerr, 1994). Hollinger (1991b) noted that if career interests are included, there can be conflict between three stereotypes: giftedness (i.e., high achiever), sex-role stereotypes (communal, social-interpersonal achievement), and occupational stereotypes (math as a male profession). These conflicts are quite powerful (Luther, Ziegler, & Goldstein, 1992) and can lead to abandoning academic achievement, avoiding math and science, opting out of gifted programs, and eliminating "masculine" career options (Hollinger, 1991b).

These conflicts are accompanied by changes in values brought on by socialization. Kerr (1994) noted that social goals (versus achievement) become salient in adolescence. Silverman (1986; 1995) found that adolescent girls come to place less value on achievement and more on sociability and social acceptance. The author noted that a talented young woman faces a "Sophie's" choice: if she chooses to be true to herself and strive for achievement, she could very likely experience disconnection from her male and female peers. If she chooses to redirect her energies into the feminine sphere (e.g., concern with boys and appearance), she will be accepted and rewarded for her efforts. As there may seem to be little apparent, immediate value in choosing achievement over social acceptance, the young woman may place greater value on social acceptance. Such a shift helps young bright females to avoid the conflict between interest in math and science and popularity, especially with males (Crawford & Gentry, 1989; Fennema & Leder, 1990).

In addition to the differences in values, a number of authors have noted that, for women more so than men, there is a societal emphasis on the value of having children, and this emphasis mitigates female achievement. Manis, Thomas, Sloat, and Davis (1989) found that for girls, and particularly talented girls, there was a conflict in assigning priorities between family or career. In a study by Fox, Tobin, and and Brody (1978), a majority of talented female students who priorized family over a full time career in a Science were significantly less likely to pursue graduate training (i.e., 36%), relative to those female students who prioritized career over family (i.e., 80%). This is consistent with Metha, Kinnier, and McWhirter (1989), who found that in most cases females assign a priority to family and devalue career and achievement. The small portion of those that do pursue science found the ability to balance career and family an important factor in their success (Subotnik & Arnold, 1995).

In a study of 67 female graduate students in education, Reis (1995) found that most felt their parents had encouraged them to place a limited value on achievement; that is, to get good grades but not to channel these efforts into careers or additional education. Further, these students felt their parents had encouraged them to go to college, but they had expected them to marry and have a family rather than pursue a career, and most felt that their career choice was a compromise due to social pressures to have a family.

Arnold (1993) found that planning to combine career and family began as early as the first year of college and that women struggled to combine achievement and family values, that is, to see an arrangement that combines high level career attainment and successful relationships. Many of these talented women viewed the conflict in achievement and family values as their greatest obstacle to achievement, and that their potential was negatively impacted by this conflict (Reis, 1995).

Stereotypes

A number of authors have found contemporary evidence of stereotyping academic domains. Hyde, Fennema, and Lamon (1990) found that girls consistently view math as a male domain. In a study exploring factors affecting attitudes towards science, Foster (1992) found that females consistently viewed math and science as white male activities. Kelly (1993) found that gifted and nongifted girls do not see themselves pursuing "masculine occupations" such as the physical sciences or engineering. These perceptions likely play a role in the change in female attitudes towards math and science noted previously (e.g., as pressure to conform to stereotypes) and, by extension, a role in the well-established trend of low female participation rates in math and science (e.g., Fox, Tobin, and Brody, 1981; Schmurak, 1996; White, 1992).

A second stereotype involves what it means to be 'feminine' in our society. Reis (1995) and Bell (1989) suggested that this entails minimizing achievement and shifting attention to social priorities (e.g., affiliation, popularity, attractiveness). Kerr (1994), Hollinger (1990), and Silverman (1995) suggested that the stereotype includes learning to conform to the expectations of others, emphasizing social-interpersonal achievement, and accepting the expectation that they will be raising a family. These societal expectations provide the basis of the female adolescent conflicts and shifts in values described above. As well, Bell (1989) noted that these expectations create a number of dilemmas for the talented female: being smart versus social (the affiliation need), media beauty (i.e., social success and attractiveness) versus marginality (i.e., high achievement), and passive versus assertive within the classroom. Noble (1989), as well as Hollinger (1991b), noted that the overt message of both stereotypes is that achievement, particularly in the 'male' domains of math and science, is not compatible with being feminine.

Biases in the Classroom

These stereotypes, as well as a number of biases, are played out in the classroom. For example, Ware, Steckler, and Leserman (1985) found that textbooks in math and science were generally written by men, using examples heavily slanted toward the male experience. In a review of five standard texts used in American schools, Rosser and Potter (1990) found that while many of the overt biases in textbooks are beginning to disappear (e.g., use of male as a generic pronoun, and the exclusion of females from illustrations), there remain more subtle biases. Specifically, the texts they reviewed pictured more males than females and pictured males more frequently in active roles. As well, those scientists highlighted in the texts were male. In a second review of contemporary school texts, Sadker and Sadker (1994) found that most texts rarely depicted women, leaving the strong impression that men dominate in science and most other areas of human endeavour. Such an impression likely discourages young women from careers in science (Kerr, 1994; Morse, 1995; Sadker & Sadker, 1994).

These stereotypes and biases are further evident in teacher beliefs. In a study of first grade teachers, Fennema, Peterson, Carpenter, and Lubinski (1990) found that teachers believed males' successes were due to ability, but females' successes were due to effort, not to ability. When asked to compare their best math students, the teachers believed that the boys were more competitive, more engaged in learning, more independent in math, and gained more enjoyment from math. Koehler (1990) found that teachers had a higher expectation of success in math for boys, and that they believed math to be a 'male' domain and thus as more useful for boys.

Peer Influence

In addition to the perceptions and actions of teachers, a number of studies have noted the influence of peers on female achievement. In a study by Campbell and Connolly (1987), it was found that males had negative perceptions of their female peers in advanced math and science classes. These male students reported that girls did not want to put in the effort that is needed in math and science, that they (the female students) did not care about how they looked, and that girls like humanities not science. Kramer (1991), as well as Callahan, Cunningham, and Plucker (1994), found that for gifted girls, there is a direct conflict between pursuing achievement and acceptance by their peer group. This conflict is heightened in the area of mathematics, as this area is stereotyped as a 'male' domain. Brown & Steinberg (1989) noted that the option frequently chosen to resolve this conflict was conformity to the peer group; more specifically, to camouflage their abilities to avoid being seen as unattractive or socially incompetent, and to get good, but not outstanding, grades. Given these peer pressures and male perceptions, taking advanced math or science courses may not appeal to a female student.

Parental Influence

A number of studies have shown the influence parents exert on female achievement. In a study by Yee and Eccles (1983), it was found that parents differ in the relative weighting of ability and effort in explaining their children's achievement. The boys' parents rated math talent as the cause of their son's success in math, and effort was seen as a significantly less important factor in math achievement. The reverse was found for the girls' parents. These perceptions have been shown to influence the child's self-perception of ability to such a degree as to override his or her perception of ability based on prior performance (Eccles, Jacobs, & Harold, 1990). Further, these self-perceptions have been shown to strongly influence the actual achievement-related choices a child makes (Eccles, 1987). That is, whether the child elects to take an additional course in a school subject. This relation between parental perceptions and child self-perceptions persists into adolescence, and is particularly strong for females and their math self-concept (Phillips, 1987; Dickens, 1990).

The parental messages that boys are naturally talented in math, while girls are talented in English, likely contributes to the female student's perception that the former is a 'male' domain. It would seem reasonable, given the strength of the parental beliefs and attributions (i.e., persisting despite their child's performance, and displacing their child's own perceptions of ability), that the young female student might eventually devalue her ability in math and fail to develop sufficient interest to persist in math and/or science.

Several studies have looked at the impact of parental expectations on the achievement of adult children. Manis, Thomas, Sloat, and Davis (1989) found that female science college majors felt their parents wanted them to "be happy," while their male peers felt their parents wanted them to pursue a career in science. Callahan et al. (1996) found that girls with high ability in math and science felt their parents, particularly their mothers, had expected them and actively encouraged them to not attend special programs in math or science. In a study of gifted female undergraduates, Reis (1995) found that parents encouraged their female children to do well in school, but they provided little encouragement to pursue a career after college. Further, these parents expected their daughters would marry and have a family. Additional education, or a career, was encouraged only if they were combined with family and/or if they permitted family to remain the priority.

The impact of these parental expectations on female students is quite significant. As noted earlier, young talented women experience a conflict over pursuing family or career (Manis, Thomas, Sloat, & Davis, 1989). Many eventually assign a priority to family rather than to pursuing a career or further education (Metha, Kinnier, & McWhirter 1989). The small portion of those that do pursue careers in science managed to balance career and family, and doing so was seen as an important factor in their success (Subotnik & Arnold, 1995). These life role expectations of family or family then career play a pivotal role in early adult achievement (Arnold, 1993).

The literature indicates that parents, teachers, peers, the presence of biases in classroom activities and texts, and the stereotyping of math and science as masculine, all negatively affect the female student. Her perceptions of her ability, her confidence, and her interests in math and science appear to be minimized and discouraged, and she is less likely to participate in advanced math and science courses (Czujko & Berstein, 1989). Leaving secondary education, parental expectations prioritizing family appear to discourage her from fulfilling her potential in the form of an advanced education and/or career, particularly in the fields of math and science (Reis, 1995).

The changes in perceptions of ability, confidence, and the conflicts and changes in values noted above appear to have a singular and additive negative impact on female achievement. Their effect in concert has been demonstrated by Eccles' (1983, 1987) Model of Achievement Motivation.

Eccles et al.'s (1983) Model of Achievement Motivation

An abundance of seemingly unconnected theories explaining gender-related patterns in achievement prompted Eccles (1983) and her colleagues to draw upon attribution, efficacy, and decision theory to develop a comprehensive model of academic choice. The model links achievement-related decisions most directly to two sets of beliefs: expectation of success and subjective value. Expectation of success is comprised of three components: perceptions of one's domain-specific abilities (i.e., self-concept of ability) and confidence in one's current and future performance within a particular domain (Eccles, 1984; 1994). Subjective value subsumes four distinct values: intrinsic, attainment, utility, and cost (Eccles, 1994).

According to this model, an individual's educational or occupational choice is guided by his or her expectations for success on, and a hierarchy of subjective values assigned to, the various achievement options. These beliefs, in turn, are affected by such factors as perceptions of task difficulty associated with each achievement option, personal goals, self-concept and self-perceptions, aptitudes, and interpretations of past experiences. The model suggests these beliefs and factors are shaped by an individual's perceptions of cultural norms and of socializers' (e.g., parents, teachers) beliefs and behaviours.

Eccles and her colleagues developed and tested their model in the early 1980's (Eccles, Adler, Futterman, Goff, Kaczala, Meece, & Midgley, 1983; Meece, (Parsons) Eccles, Kaczala, Goff, & Futterman, 1982). Using data from the initial stages of a seven-year longitudinal study, they confirmed the models predictions. Task value, perceived task difficulty, and expectations for success were found to predict math course enrolment. Eccles, Adler, and Meece (1984) compared the model to competing theories purporting to explain gender differences in achievement. Two hundred students in grades eight through ten were given the following attitudinal measures regarding Math and English: self-concept of ability, subjective task value, perceived task difficulty, and continuing motivation. In the second year of the two year study, one hundred and forty two of the subjects were asked for their estimations of ability, expectations for success, and causal attributions, regarding several math tasks. As well, teacher estimations of student learned helplessness were garnered for all subjects in year one of the study. The authors found little predictive power in learned helplessness and attribution theories explaining gender patterns in course enrolment. Their achievement model, however, predicted course enrolment and accounted for the observed gender patterns in enrolment.

Having established the model, Eccles and her colleagues began exploring in more detail the relations between the model's attitudinal factors. They found that intrinsic and utility task values, more so than expectations for success, predicted achievement plans. Moreover, sex differences in perceived task value predicted sex differences in eventual math course enrolment and sports participation (Eccles, 1984, 1989; Eccles (Parsons), Adler, & Meece, 1984; Eccles & Harold, 1991). Expectations of success, for both males and females, were found to be primarily related to an individual's actual performance levels, as reflected in current grade or GPA (Eccles, 1987; Eccles & Jacobs, 1986).

In an attempt to explore the relations between the model's expectancies and value factors, Eccles and her colleagues performed several factor analyses on these components. Eccles and Jacobs (1986) confirmed the separability of the factors: perception of task difficulty, subjective task value, and ability perceptions. Eccles and Wigfield (1995) confirmed the intrinsic, utility, and attainment components of the model's value factor. They found that the perceptions of task difficulty factor had two components: perceptions of task difficulty and perceptions of effort needed to do well. Further, their analysis indicated that the ability perceptions factor entailed, as expected, perceptions of ability (domain-specific self-concept of ability), personal efficacy (confidence in one's current performance), and expectations for success (confidence in one's future performance).

The relations among the social and attitudinal factors of the model have been extensively explored as well. For example, Eccles and her colleagues found that parent attitudes, beliefs, and perceptions are critical mediators of a child's academic and self beliefs (Eccles 1986; 1992). More specifically, Jacobs, Eccles, and Harold (1990) found that parental perceptions of child ability, and of task difficulty, mediated the influence of past performance on a child's ability perceptions. Eccles (1992) found that a mother's gender-role stereotypes interacted with the sex of the child, resulting in an overestimate of the child's ability, if the ability was in the direction of the stereotype. These parental, stereotypical beliefs and perceptions were found to influence task value for both male and female children, resulting in gender-related patterns in activity choices (Eccles, Jacobs, & Harold 1990; Eccles, Jacobs, Harold, Yoon, Aberbach, & Doan, 1991).

A number of studies have shown the impact of school and teacher influences on a child's achievement-related decisions. Eccles and Jacobs (1986) found that teacher estimation of student ability influences a student's perceptions of task difficulty and ability. Midgley, Feldlauer, and Eccles (1989a), as well as Eccles, Lord, and Midgley (1991), found that declines in junior high school students' expectations for success, personal efficacy, and perceptions of task difficulty paralleled declines in teacher self-perceptions of efficacy. In a second study, Midgley, Feldlaufer, and Eccles (1989b) found a relationship between teacher support and subjective task value. Students who initially had a teacher providing them with low support and then a teacher providing high support significantly increased their subjective value of the subject matter taught by the teachers.

In addition to ongoing work exploring influences on educational choices, Eccles and her colleagues have been examining occupational choices (Eccles, 1987; Eccles, 1994; Eccles & Harold, 1992). In a recent study, Eccles, Jozefowicez, Barber, and Belansky (1993) found that Eccles model applied to career decisions. More specifically, expectations for success and task value influenced career aspirations and predicted eventual career choice. As well, Jozefowicez, Barber, and Eccles, (1993) found that personal efficacy (i.e., ability perceptions, a component of expectations for success) for various occupations was a significant predictor of occupational choice.

Eccles and her colleagues have established a comprehensive model detailing a number of critical influences on a student's educational and occupational choices. Whether gifted or average in ability, an individual's choice of school subjects, sports activities, or career is influenced by his or her expectations for success on the various choices, and the personal values assigned to these choices. Eccles has shown that the achievement-related choices one makes are determined by the expectations for success one has for a particular achievement option (whether a course or career), and the value one assigns that particular option. Expectations, in turn, are influenced by self-schemas (e.g., self-confidence), perceptions of ability, and perceptions of task difficulty. The value of a particular achievement option is influenced by its utility value (how useful it will be), attainment value (the match between who you are and the characteristics of the course or career), and cost value (needed effort to succeed). The research on perceptions and confidence noted above suggest lower female expectations for success in math and science. Findings regarding attributions indicate that females perceive math and science as being difficult tasks with a higher cost value. The findings on attitudes towards math and science indicated change was, in part, due to low utility value. The conflicts and changes in values noted previously, as well as the male stereotyping of math and science noted earlier, change the attainment and cost value of math and science. These subjects come to be viewed as a mismatch between being feminine and doing math or science. As well, pursuing the latter comes at the high cost of balancing multiple roles. Given the impact on the various components of expectations for success and value, it is not surprising that females fail to persist in math and science (Hollinger, 1991b; Schmurak, 1996; Zorman, 1996).

Eccles (1987) noted that these psychological constructs are influenced by social factors. She has shown that both expectations for success and the value assigned to achievement choices (whether a course or career) are shaped by gender-role schema; more specifically, that gender-role socialization (and the resulting internalized schema) shape the values a student assigns to perceived options. The stereotypical nature of the socialization creates a general concordance between stereotypical gender schema and career interests and choices (Eccles & Harold, 1992). This concordance is reflected in the continuing female trend to choose stereotypical courses and careers (Hall & Kelly, 1995; Reis & Callahan, 1989). A number of authors have identified a range of social factors that contribute to gender socialization in a manner that discourages persistence in math and science.

Recent work by Eccles and her colleagues has been exploring the factors underlying the achievement-related choices of young adults. In a study currently underway, Eccles and her colleagues have surveyed several U.S. college undergraduate populations, collecting data on values, expectancies, and several mediator variables.

Although the body of research supporting Eccles' model (Eccles et al., 1983; Eccles, 1987) is extensive, there are numerous limitations. Eccles and her colleagues have not explored her model in relation to minority populations. This seems particularly relevant as values (e.g., attainment and utility) play a prominent role in her model, and the influence of such values on choice may be affected (e.g., overshadowed) by the presence of minority cultural, racial, and/or socio-economic values.

A second limitation in the literature is the absence of research exploring the influence of psychological development on Eccles' model (Eccles, 1987; Eccles et al., 1983). By way of example, existing research on identity development (e.g., Marcia 1976, 1980; Meilman, 1979, Orlofsky, 1979) indicates that several aspects of achievement (e.g., degree of vocation commitment, grade point average, degree of difficulty of chosen major) vary in relation to four identity statuses (i.e., identity-diffused, foreclosure, moratorium, and identity-achieved). Might these statuses also influence constructs in Eccles' model of achievement motivation (e.g., the construct General Self-Schemata)?

In addition to the limitations noted above, there are two avenues that have not been explored and that might contribute to our understanding of persistence in the Sciences. Research on this model has focused on confirmation of its ability to predict gender differences in the course selection of secondary students and the occupational choices of adults. However, the model has not been explored in relation to undergraduate students and the question of female persistence in Science. This student population is of particular interest when considering the question of persistence, as it is during the undergraduate years that students make decisions about pursing education in a particular discipline. They have an opportunity to explore and follow their interests (whether intrinsic, utilitarian, or both), and they must commit to a major in a specific academic discipline. Thus, exploring this population allows for the possibility of examining these two circumstances as elements of persistence (i.e., academic interests, as reflected in favourite subjects, and commitment to a major, an act that is reflective of persistence). Moreover, exploring the relationships among gender, Eccles' constructs, and these elements of persistence would permit addressing such questions as: Does Eccles' model predict elements of persistence (i.e., student interests and commitment to a major) given its ability to predict student course selection? Are there gender differences in the role Eccles' model plays in student interests and student commitment to a major? Exploring these questions in a student population making critical academic and career decisions may further our understanding of female persistence in Science.

A second avenue suggested by the literature supporting Eccles' (Eccles et al., 1983; Eccles, 1987) work is exploration of her model in relation to models that influence student learning. As previously noted, Eccles' research has focused on confirmation of the model's ability to predict the course selection of secondary students and the occupational choices of adults. There has been no research exploring the model's relationships to constructs (i.e., models) affecting learning.

There are, however, several studies in the field of Epistemology that suggest a relationship between models of epistemology, which are known to influence student learning, and Eccles'(Eccles et al., 1983; 1987) constructs. Touchton, Wertheimer, Cornfeld, and Harrison (1977) mounted a college career development course based on Perry's (1968) epistemological model. They surveyed and matched student epistemological stance with course presentation materials and content. Students assigned a high level of value to the course and a high level of confidence in the subject matter; responses that suggest high utility value and high personal efficacy, respectively. Tobin, Tippins, and Hook (1995) found that differences between teacher and student epistemology produced student frustration and disempowerment, a view of science as difficult, and a student focus on 'just' obtaining a passing grade. These student responses suggest reduced personal efficacy, an increase in perceptions of task difficulty, and reduced expectations of success.

In the two studies, student responses suggested that a match in epistemology affected utility values, personal efficacy, perceptions of task difficulty, and expectations of success, all of which are elements of Eccles' (Eccles et al., 1983; 1987) model. Although these studies did not directly examine the connection between epistemology and achievement decisions, their findings do suggest that there is a relationship between epistemology and Eccles' model.

Epistemology and Learning

Psychological research on epistemology began with the work of Perry (1968). He developed a model of epistemological development based on the questionnaire responses and interviews of male Harvard University undergraduates. His model indicates that many students enter university with a dualistic view of the world. That is, they view the world in black-or-white terms, and they believe the knowledge transmitted by authority to be absolute in nature. As these students encounter varying opinions, they begin to acknowledge uncertainty and this eventually prompts them to shift to a position of relativism, the view that knowledge is relative, contextual, complex and tentative. The perceived source of knowledge shifts as well, from authority as arbiter of knowledge to self as a maker of meaning (Perry, 1968; Schommer, 1994; Hofer & Pintrich, 1997). These shifts are then followed by commitments to values, careers, relationships, and personal identity.

Perry (1968) explicitly placed his model within a Piagetian (1950) context, and he borrowed a number of the latter's constructs to explain movement through his own model. He noted that his 'scheme' would be "... at a level as yet unexplored in Piaget's publications – a period of philosophizing in which the capacity for meta-thinking emerges" (p. 12). Progress through this scheme or model was attributed to Piagetian 'de-centering' and 'accommodation/assimilation', "... in those structures (roughly Piaget's "schema") through which the person finds meaning in his experiences" (p. 12). This positioning of his model as post-Piagetian cognition was largely taken up by subsequent researchers in the field (e.g., Schommer, 1990; 1994). As well, his work articulated the Dualistic, Multiplistic, and Relativistic epistemological positions taken up by the field in general (e.g., Baxter Magolda, 1995, King & Kitchener, 1994, Schommer, 1990).

Since Perry's (1968) work, a number of researchers (e.g., Baxter Magolda, 1995; Schommer, 1990, 1994) have investigated the links between epistemology and academic learning and performance. A brief review of this research is presented below.

Student Perceptions

Baxter-Magolda (1992) employed open-ended interviews and a questionnaire to detail the influence of epistemology on a student's perception of the roles that the learner, peers, instructor, and academic evaluation play in the typical classroom. As students move from the dualist to relativist stage, their views of the role of the learner progress from that of an acquirer of knowledge to an integrator and applier of knowledge. The perceived role of peers changes from transmitters of knowledge to resources which contribute ideas and elaborations of knowledge. The view of the instructor's role changes from that of a communicator of knowledge to a promoter of knowledge embedded in context, and as a promoter of evaluative discussions of the underlying perspectives of knowledge. The view of evaluation in the classroom shifts from that of a vehicle which shows the instructor what a student has learned to a tool which allows the student and instructor to work toward learning goals and to measure this progress.

Baxter-Magolda's (1992) research on epistemology and learning compliments research by a number of authors who have examined the affect of teacher and student epistemologies on student perceptions. A review of this work is presented below.

Teacher-Student Epistemology

In a study by Hofer (1994), the impact of two approaches to teaching math were explored. One college class received the conventional approach to math, which has been described as objectivist and dualistic (e.g., Roth & Roychoudhury, 1994), and a second class received a constructivist (or relativist) approach to math, defined as portraying knowledge as personal, constructed, and tentative (Roth & Roychoudhury, 1994). Hofer found that students held objectivist views towards math and strongly resisted the teacher's constructivist approach to math. Resistance generally took the form of "But this isn't math" (Hofer, 1997; p. 129).

In a study of career development, Touchton, Wertheimer, Cornfeld, and Harrison (1977) implemented a college career development course based on Perry's (1968) epistemological model. They surveyed and matched student and teacher epistemological stance with course presentation materials and content. Students assigned a high value to the course as a whole, and they felt a high level of confidence in the subject matter.

These studies indicate that student and teacher epistemologies (and the particular epistemology implied by the structure and content of the course) play a role in student learning. The perceptions of the roles of learner, peer, instructor, and evaluation in learning vary by epistemological stance (Baxter-Magolda, 1992). A mismatch between teacher and student epistemologies produces student resistance, frustration, and disempowerment (Hofer, 1994). A match in epistemology produced increased student confidence in course subject matter (Touchton et al., 1977). Although these studies identified the influence of epistemology on student behaviour and perceptions, they did not examine student achievement.

Additional research examining epistemology and learning has shown epistemology's influence extends to engagement in learning, task persistence, text comprehension, and coping with open-ended problems. A brief review of this research is presented below.

Active Engagement

Research by Baxter-Magolda (1992) and Belenky et al. (1986) indicate students with a dualist (or silent, receiving) epistemological stance take on a passive learning role. That is, they receive information but do not actively question or engage the instructor.

This passive acceptance of information has been found in studies exploring beliefs about historical knowledge. For example, Fournier and Wineburg (1993) found that dualist students (i.e., those believing historical accounts were objective fact) believed that accounts of history should be passively accepted as written. Relativist students (i.e., those believing the passages were tentative, contextual accounts of history) believed that historical accounts are open to interpretation and questioning.

Persistence

In a study examining epistemology's role in reading, Schommer (1990) found that a belief in quick all-or-none learning (i.e., Schommer's Quick Learning belief) negatively affected students' persistence in understanding a complex reading passage. In a study on math problem solving, Schoenfeld (1988) found a belief in quick learning reduced student persistence on difficult math problems. Many of his high school subjects felt math problems should be solved within five to ten minutes and that any more time spent was a waste of time.

Comprehension

In a study exploring reading comprehension in college students, Ryan (1984) drew a subset of items from Perry's (1968) epistemological questionnaire and classified students as dualist (knowledge is certain) or relativist (knowledge is uncertain and context dependent). He found that when dualists were asked how they knew they had understood something, they indicated being able to recall factual information. Relativists, on the other hand, indicated being able to use knowledge in new situations. Schommer (1988) found that a belief in quick learning predicted poor performance on class tests and overconfidence in text comprehension. In a study involving comprehension of social, math, and physical science texts, Schommer (1990) found a belief in quick learning and certain knowledge (a dualist belief) predicted poor monitoring of comprehension. As well, the more students believed in quick learning, the less they understood the text they had read. Further, students with strong beliefs in simple knowledge (a dualist perspective) distorted passage information, interpreting the tentative knowledge in the text as fact.

Epistemological beliefs have been found to influence the integration of information within text. For example, a dualist belief about the nature of knowledge, that knowledge is best viewed as a compendium of facts, has been shown to slow the acquisition and integration of scientific concepts (e.g., Songer & Linn, 1991; Clemison, 1990) and mathematical concepts (Schoenfeld, 1985, 1988). Songer and Linn (1991) found that high school students with a dualist view of knowledge believed learning in science meant memorizing words and facts. In contrast, those students with a relativist stance towards knowledge noted learning meant understanding and connecting science ideas, and that "..some times the facts don't give you all the information you need" (p. 770). The authors indicated that the relativist-oriented student tended to acquire science concepts more readily than did the dualist students. This research suggests teachers can foster student comprehension by being aware of and addressing epistemology's impact on students' integration of text information.

Open-ended Problems

Beliefs about knowledge and learning have been shown to influence student performance on problems where there may be more than one right answer, more than one route to solve the problem, or there may not be any clear cut answer. As previously discussed, Dweck and Leggitt (1988) found that children who believe intelligence is fixed (in Schommer's model, Fixed Ability) tended to perseverate in strategies and then give up when faced with difficult, ill-structured problems.

In a study of constructivist and performative epistemologies, the latter being similar to Perry's dualist position, Bryson (1993) found that students with a performative stance (which included a strong belief in fixed ability and certain knowledge) employed basic strategies in approaching a solution to a research task. This was illustrated by one of the subject's research strategies, " to go to the library and look in a book. Sometimes they have the answer right away, and then you can stop."(p. 310). Constructivist students tended to have additional strategies, as described by one subject, " I would probably go down to the library and look through the cabinets of books...But then I'd probably have to take a trip to the university and talk to the experts...Lots of things you need to know aren't in books" (p. 310).

In summary, the research examining links between epistemology and learning indicates the former has a critical impact on learning. Conceptions of knowledge and learning affect engagement in learning, persistence on tasks, comprehension of text material, and the selection of academic strategies. As well, such beliefs have been found to influence the relationships between students and teachers, and the students' perceptions of the roles the learner, peer, instructor, and evaluation play within the classroom.

There are several prominent models in the field of epistemology that, if examined in relation to Eccles' constructs, gender, and Science, may contribute to our understanding of female persistence in the Sciences. These are reviewed below.

Schommer's (1990, 1994) Model of Epistemological Beliefs

Schommer (1990) began her research by examining the work of Perry (1968), Belenky et al. (1986), and Kitchener and King (1981). She suggested the mixed findings in the field regarding links between learning and personal epistemology reflected the general assumption that epistemological beliefs were unidimensional and progressed through fixed stages. She reconceptualized epistemological beliefs as a multi-dimensional system of relatively independent beliefs, and she then tested this reconception via factor analysis. The statistical analysis produced the four dimensions (factors) currently constituting her epistemological model: *Fixed Ability*, which ranges from the belief that the ability to learn is fixed at birth to the belief that the ability to learn can be improved over time; *Quick Learning*, which ranges from the belief that learning occurs in a short amount of time, or not at all, to a belief that learning is gradual; *Certain Knowledge*, which ranges from the belief that knowledge is certain and absolute to the belief that knowledge is tentative and contextual; and *Simple Knowledge*, which ranges from the belief that knowledge is best thought of as isolated facts to the belief that knowledge is characterized as complex, interrelated ideas.

These factors were replicated in a second college sample, and in both gifted and nongifted high school populations (Schommer, 1993; Schommer & Dunnell, 1994). As well, these latter studies provided evidence supporting the epistemological model's assumption that epistemological beliefs are relatively independent. By way of example, Schommer (1993a) found that, as the study's gifted subjects proceeded through high school, their beliefs in simple knowledge and quick learning became more sophisticated (i.e., they reduced their endorsement in these beliefs), while their beliefs in fixed ability and certain knowledge did not change.

Schommer's (1990,1994) model has been linked to a variety of learning processes. Schommer (1988) found that a belief in quick learning predicted GPA (after controlling for IQ), poor performance on class tests, and overconfidence in text comprehension. Moreover, a belief in quick learning and simple knowledge have been found to predict poor comprehension of social, math, and physical science texts, and poor monitoring of comprehension (Schommer, 1990). A belief in simple knowledge has been shown to negatively influence the integration of information (Songer & Linn, 1991; Spiro et al, 1988). Bryson (1993) found that a belief in fixed ability negatively affected the nature of strategies used in problem-solving. Dweck and Leggett (1988) noted that fixed ability negatively influenced persistence on math and reading tasks. Finally, a belief in certain knowledge had been shown to reduce the degree of engagement in learning (Schommer, 1994).

In addition to the above findings linking specific epistemological beliefs and aspects of learning, Schommer (1993b, 1994) found that most epistemological beliefs grow in sophistication as an individual proceeds through high school and college. Schommer and Dunnell (1994) found that gifted and nongifted students begin high school with similar levels of epistemological sophistication. By the end of high school, gifted students, but not average students, significantly reduced their levels of belief in simple knowledge and quick learning. For both populations, beliefs in fixed ability and certain knowledge remained unchanged. As well, across both populations, males were more likely to believe in fixed ability and quick learning. This gender difference has been found in a second study (Schommer, 1990), though the practical implications have not yet been examined in the epistemological literature.

Recently, Schommer (1994) elaborated upon her conceptualization of epistemological beliefs. She has suggested each belief is best characterized as a frequency distribution. In place of the continuum, she proposed that an individual may believe most knowledge is certain, some is temporarily uncertain, and little is tentative. Positing such distributions, Schommer suggested, captures more accurately, the complexity of epistemological beliefs. This refinement in Schommer's model has yet to be empirically tested.

Schommer's (1994) research has been described as the most quantitative and analytical of the existing models of epistemology (Hofer & Pintrich, 1997), and her efforts, as well as those using her model, have provided a large body of information detailing the links between epistemology and student performance. The model, however, has a number of limitations. For example, her statistical work on her questionnaire has been criticized for not including a factor analysis on individual questionnaire items (e.g., Hofer & Pintrich, 1997). Moreover, several authors have reported a range of statistical properties for Schommer's Epistemology Questionnaire. Jehng (1993) administered Schommer's questionnaire, substituting the Simple Knowledge belief item set with an

Orderly Process belief set (drawn from Spiro et al., 1988). He employed a Cronbach's Alpha reliability index on the questionnaire and found 1) approximately 20% of Schommer's items had correlations of less than .10, and 2) an additional seven items had low sub-scale discrimination capability. Jehng deleted the seventeen items from the scale, which then raised the questionnaire's overall reliability to .84, though subscale item sets (Quick Learning, Fixed Ability, Certainty of Knowledge) continued to have reliabilities that ranged from .42 to 59. Notwithstanding the low subscale reliabilities, Jehng deemed the questionnaire as "...acceptable for group comparisons" (p. 28).

A second concern with Schommer's (1990; 1994) scale lies in the area of content representativeness. In a review of the personal epistemology literature, Hofer and Pintrich (1997) noted that items on Schommer's Epistemology Questionnaire were phrased in either the first or third person, "making it difficult to determine whether the respondent is referring to personally held epistemological beliefs or perceptions of others' generalized beliefs" (p. 110).

Notwithstanding the scale-related concerns, the literature indicates the beliefs comprising Schommer's model have a subtle but critical impact on learning (Schommer & Donnell, 1994). Although this body of literature is substantial and growing, Schommer's (Schommer, 1990; 1994) model has not been examined in relation to other models affecting student learning, particularly student achievement-related decisions, or in relation to female persistence in Science.

Belenky et al.'s (1986) Women's Ways of Knowing

Belenky, Clinchy, Goldberger, and Tarule (1986) interviewed 135 female students and subsequently developed a Women's Ways of Knowing model of epistemology. Focusing primarily on the source of knowledge (Clinchy, 1989), these authors purposed five epistemological perspectives, "... from which women know and view the world" (Belenky et al., 1986, p. 15). In the *Silence* and *Received* perspectives of this model, which parallels Perry's (1968) dualist position, women view knowledge as absolute and external to themselves. In the *Subjective* perspective, knowledge is still viewed as absolute but its source has moved to within the self. In the *Procedural* perspective, women come to apply objective, systematic procedures of analysis on knowledge. This application can take two forms: a) separate knowing, where the knower takes an impersonal and detached stance towards knowledge (as exemplified in critical thinking and the Scientific Method), or b) connected knowing, where the knower takes a personal approach to knowledge and emphases understanding rather than judgement. In the final perspective, *Constructed* knowledge, women integrate the separate and connected strategies for knowing. They view the self as an integral part of knowing and they believe knowledge to be constructed and context bound.

Since the publication of Women's Ways of Knowing in 1986, considerable use has been made of the model by educators in such fields as counselling (e.g., Enns, 1993), psychotherapy (Mahoney, 1996), law (e.g., Ingulli, 1992), and nursing (e.g., Eyres, Loustau, & Ersek, 1992). As well, the authors of the model, and subsequent researchers, have explored its application in the areas of post-secondary and adult education (e.g., Carfagna, 1995; Clinchy, 1990; Clinchy, 1995; Enns, 1993; Lyons, 1990). For example, drawing upon the ideas of 'connected' knowing, 'connected' classes, and teacher as 'mid-wife,' ideas that developed out of the original work of Belenky et al. (1986), educators have reconsidered traditional curriculum and pedagogical practice as they developed and established Women's Studies programs in the U.S. (Carfagna, 1995; Musil, 1992). In addition, educators have drawn upon these ideas in their attempts to recruit and retain female students in U.S. Colleges (Stanton, 1996), and to promote greater understanding (i.e., knowledge of, and the personal relevance of, subject matter) in various disciplines (e.g., Clinchy, 1995; Trumbull & Keer, 1993).

The changes in pedagogical practices and curriculum noted above have generally had positive results (Butler, Cloyer, Homans, Longenechker, & Musil, 1991; Morrow & Morrow, 1993; Stanton, 1996). This is encouraging, given the difficulties female students experienced when, as 'connected' knowers, they encountered 'separate' (i.e., traditional) pedagogical practices in the classroom (Belenky et al., 1986).

In their original work, Belenky et al. (1986) found that a mismatch between student and course approaches to knowing had a significant negative effect on female students. The student reactions are conveyed in Belenky et al.'s comments:

> Being recipients but not sources of knowledge, the students felt confused and incapable when the teacher required that they do original work. Angela had a professor who burdened her with just such expectations. She said he was wrong – "wrong in his method of teaching," not, of course, "wrong because of what he said." Knowing all the "right answers" himself, the professor refused to pass them

> on. "He would make you feel stupid. He would make you find the answers on your own. And he wouldn't even give you any hints on what the right answers were." How could she learn if the teacher refused to pass along the knowledge?" (p.40)

The quote above illustrates Belenky et al.'s finding that female students with a 'connected' approach to knowing who were exposed to 'separate' pedagogical practices reported feeling disconnected and alienated from 'separate' knowledge. This problem was "particularly acute with respect to Science" (Belenky et al., 1986, p. 215). A subsequent study found a similar reaction to Science (i.e., alienation and disconnection) by women who were not attending a post-secondary institution (Barr & Birke, 1994).

Belenky et al. (1986) noted that, in addition to feelings of alienation and disconnection, "connected knowers struggle with understanding and developing a 'separate' Way of Knowing, and in their attempts to do so, end up suppressing the self and feel that they were not "making themselves heard" (Belenky et al., p. 199-200). Occasionally, the authors noted, "this tension prompts them to leave courses and/or university because their only tool for knowing has been challenged and taken away" (Belenky et al., p. 202). These findings suggest that female students with a 'connected' way of knowing experience significant tension when exposed to 'separate' pedagogy. How do female students resolve this epistemological tension when committing to a Science, a discipline noted for its 'separate' approach to pedagogy (Belenky et al., 1986; Barr & Birke, 1994; Bendixen, Dunkle, & Schraw, 1994)? Do they adopt a 'separate' approach to knowing? Does this adoption extend to their personal lives, as well as to their academic lives? Exploring how this epistemological tension is resolved may provide a greater understanding of the factors influencing persistence in Science.

Waterman's (1982) Model of Science Epistemology

One model of epistemology that suggests a direct relationship between epistemology, Science, and Ways of Knowing is Waterman's (1982) Model of Science Epistemology. Waterman surveyed 364 undergraduate Biology students to obtain an initial sense of their conceptions of Science knowledge. She then conducted two interviews with thirty students drawn from the survey sample. The themes developed from the interviews resulted in the identification of three epistemological positions relating to Science knowledge. These were the *Traditional*, *Modified-Traditional*, and *Contemporary*. The *Traditional* view depicts Science knowledge as discovered and based on absolute, observable facts, and as additive rather than tentative in nature. The *Modified-Traditional* view suggests that Science knowledge is discovered and based on observed, absolute facts, but it remains tentative and changeable in nature due to the limitations of the scientific method and/or human senses. Finally, the *Contemporary* view portrays Science knowledge as products of the human mind (i.e., constructed rather than discovered), and as being probabilistic, rather than absolute, in nature.

The conceptions of science epistemology noted above are consistent with those used by many current researchers exploring the role of science epistemology in learning Science (e.g. Carey & Smith, 1993; Hammer, 1994). As well, the 'Traditional' and 'Modified-traditional' views appear to be consistent with a 'separate' Way of Knowing. Specifically, Waterman describes the Scientific Method as the "operational basis of the

'Traditional' and 'Modified-traditional' views of Science" (p. 8). Belenky et al. (1986), as well as Clinchy (1989a; 1989b; 1996), have described the Scientific Method as the primary tool of 'separate' knowing. Given this commonality, a relationship between approaches to knowing and conceptions of Science knowledge is suggested. To date, this possibility has not been explored empirically.

In addition to this commonality, there may be a similarity in terms of effect when Science pedagogical epistemology differs from student epistemology. As previously noted, Belenky et al., (1986) identified an epistemological tension that develops when 'connected' knowers are exposed to 'separate' pedagogical practice. A second possible source of epistemological tension may occur when Science students hold conceptions of Science knowledge that differ markedly from those held by their instructors and the Science curriculum. The literature exploring Science epistemology indicates secondary and post-secondary students generally hold theories and conceptions of Science that are 'traditional' or empiricist in nature (e.g., Grosslight, Unger, & Jay, 1991; Ryan & Aikenhead, 1995; Waterman, 1982) despite efforts by American and Canadian Science instructors (and Science curriculums) to promote a 'constructivist' approach to Science (Carey & Smith, 1993; Edmonson & Novak, 1993; Nadeau & Desautels, 1984). Such a mismatch has been shown to negatively affect the teaching-learning process (Schon, 1987; Goldberger, Tarule, Clinchy, & Belenky, 1996; Tobin, Tippins, & Hook, 1995). Given this effect, the impact of the mismatch in Science epistemology on the teaching-learning process may be a source of epistemological tension that may affect, either singularly, or in concert with the epistemological tension described by Belenky et al.

(1986), the willingness of female students to persist in Science. This possibility has not been explored, empirically.

Summary

Researchers exploring women's achievement, and their pursuit of advanced education and careers in Science, have identified numerous individual constructs and social factors which influence women to pursue education and careers in fields other than Science, though they are as capable as their male counterparts. These factors exert their influence individually and in concert, as demonstrated by the literature supporting Eccles' (Eccles et al., 1986) Model of Achievement Motivation.

Although this model is well supported by research, it has not been examined in a post-secondary population, where students make decisions about pursuing a field and a career. In addition, the model has not been explored in relation to other models known to affect student learning. One model, Schommer's (1990; 1994) Epistemological Beliefs, has demonstrated the significant impact epistemology has on a variety of learning processes, and supporting research suggests it may affect a number of Eccles' constructs. Exploring the relationship between Eccles' constructs, which affect student decisions, and Schommer's beliefs, which affect student learning, across two elements of persistence in a post-secondary population (i.e., student interests and commitment to Science) may further our understanding of female persistence in Science.

Additionally, research underlying two models of epistemology indicate the possibility of epistemological tension as an additional obstacle to female persistence in Science. Specifically, research supporting Women's Ways of Knowing (Belenky et al.,

1986) indicated that differences between student and discipline epistemologies (i.e., female 'connected' knowers and 'separate' pedagogy) significantly and negatively affect female students. Exploring the nature of the adjustment to instruction in a discipline that female students make when committing to a Science may contribute to our understanding of persistence in Science.

A second epistemological model, Waterman's (1982) Science Epistemology, articulates two conceptions of science epistemology ('Traditional' and 'Modified-traditional') that are similar to Belenky et al.'s (1986) conception of 'separate' knowing. Such a commonality suggests the possibility of a second source of epistemological tension that may produce alienation similar to that identified by Belenky et al. (1986). The present study explores the nature of this commonality (i.e., the possibility of a relationship), as a preliminary step to examining the relationship's affect on female persistence in Science.

CHAPTER III

Method

This chapter is divided into five sections. The first will address the recruitment and characteristics of the study's participants. Following this are sections discussing the research instruments, data collection procedures, and data scoring procedures. The chapter will then conclude with the procedures employed to analyze the data. These procedures will be described as they pertain to the research questions in the present study.

Participants

The pool of participants in the present study entailed one hundred and fifty-one undergraduate students between the ages of 18 and 35. Forty-one of the study's participants were randomly selected from a pool of 1991-1995 participants in the Shad Valley program, a university-based summer program for high school students excelling in Science (i.e., Math, Chemistry, Physics, Biology, and Engineering). At the time of this study, the students had graduated from the program and were attending post-secondary institutions across Canada.

The Shad Valley participants were selected because of their talents, interests, and achievement in Science, which is the general field of interest in this study. Further, their successes might indicate strong expectations for success, self-concept of ability, and subjective task values, and thus provide a good opportunity to test the variables in this study. To guard against limiting the study's findings to this group of students, there was a need to access a broad pool of typical undergraduate students with talents, interests, and success in Science, as well as nonscience disciplines. Towards this end, the remaining participants in the present study (i.e., 110 participants) were obtained from two sources: fifty-four students were randomly drawn from a general undergraduate psychology course at a college in Western Canada, and fifty-six students were randomly drawn from several sections of a general undergraduate education course at a university in Western Canada.

Research Instruments

The instruments and interview questions used in this study were drawn from the works of Eccles et al. (1983; Eccles, 1987), Schommer (1990; 1994), Belenky et al. (1986; 1997), and Waterman (1982). The instruments were completed by all three groups of participants (i.e., the college, university and Shad Valley groups). In addition, the Shad Valley group responded to the interview questions. Samples of the instruments and interview questions used in the current study are provided in Appendix A.

Eccles et al.'s (1983) Scales

Expectations for success, subjective task values, and self-concept of abilities were assessed by Eccles et al.'s College Questionnaire (see Appendix A.1). The instrument was first administered during the final (i.e., 1992 – 1993) phase of Eccles et al.'s longitudinal study of adolescent life transitions (Eccles et al., 1983). Subsequent factor analyses on the questionnaire's scales indicated all items loaded on their respective scales in the range of .60 to .89 (Eccles et al., 1997, personal communication). A confirmatory factor analyses is underway (Eccles et al., 1998, personal communication).

There were a number of variables on the college instrument which were not germane to the current study, such as items pertaining to racism, sexism, and military service. These items were deleted from the questionnaire. Further, several demographic variables were appended to the questionnaire (see Appendix A.2).

In the present study, a Cronbach's Alpha reliability analysis was completed on Eccles' (Eccles et al., 1983) scales. Table 1 displays a comparison of the scales' alpha values obtained in the current study with the alpha values obtained by Eccles et al (1998, personal communication). As Table 1 suggests, six of the nine alpha values in the current study fall in the range of fair to good reliability (i.e., .71 to .86), and are thus similar to those reported by Eccles. The following scales with fair to low reliability were retained in subsequent analyses as they are of theoretical interest: Expectations for Success (alpha = .68), Attainment Value: Major (alpha =.68), Utility Value: Job (alpha =.58). Further, the following scales each contain two items and were retained in subsequent analyses due to their theoretical value: Utility Value: Courses, Self-Concept of Ability: Social Sciences, and Self-Concept of Ability: Advanced.

Table 1
Cronbach Alpha Reliabilities: Eccles et al.'s (1983) Scales

Scale	Cronbach's Alpha (Current Study)	Cronbach's Alpha (Eccles Study)
SCA[1]: Major	.71	.71
SCA: Eng (Engineering/Math/Science)	.86	.89
SCA: Social Sciences	.76	.72
SCA: Advanced	.83	.78
Expectation for Success	.68	.89
Utility Value: Courses	.80	.83
Utility Value: Job	.58	.72
Attainment Value: Major	.68	.77
Attainment Value: University	.74	.75

[1]Self-Concept of Ability

Schommer's (1990,1994) Epistemology Questionnaire

Epistemological beliefs were assessed via Schommer's Epistemological Questionnaire (See Appendix A.3). The instrument has been used by numerous authors to explore the presence and influence of epistemological beliefs in a variety of populations, including several college populations (e.g., Schommer, 1990; Schommer, Crouse, & Rhodes, 1992).

Schommer (1993b) reported a questionnaire test-retest reliability of .74, and subscale reliabilities ranging from .68 to .85 (Schommer, 1993b). However, several authors (e.g., Jehng, 1993) have reported lower psychometric properties for the questionnaire (e.g., .42 to .59). As well, a recent review (Hofer & Pintrich, 1997) noted that many items on the questionnaire used a third person referent, "making it difficult to determine whether the respondent is referring to personally held epistemological beliefs or perceptions of others' generalized beliefs" (Hofer & Pintrich, 1997, p. 110). Given these concerns, the questionnaire's items were rephrased to reflect a first person referent. For example, the item "The only thing that is certain is uncertainty itself" was changed to "I believe that the only thing that is certain is uncertainty itself." The adapted questionnaire used in the current study is provided in Appendix A.4.

In addition to rephrasing items, the internal consistency of the questionnaire was explored by obtaining subscale Cronbach's alpha reliabilities and Pearson Product Moment Correlations. The questionnaire's original alphas and correlations were requested from Schommer, but the data was unavailable for this study.

The questionnaire's Cronbach alphas are presented in Table 2. As the table illustrates, three of the four subscales obtained low to fair reliability (i.e., .63 to .70). Certain Knowledge was of questionable reliability (i.e., .48), and was not included in subsequent analyses.

Table 2
Cronbach Alpha Reliabilities: Schommer's (1990) Epistemology Questionnaire

Scale	Cronbach's Alpha
Quick Learning	.63
Fixed Ability	.64
Certain Knowledge	.48
Simple Knowledge	.70

Pearson correlations for the four subscales are listed in Table 3. As the table indicates, correlations among the subscales suggest Certain Knowledge and Simple Knowledge are measuring different constructs, as are Quick Learning and Simple Knowledge. Further, the strength of the correlation between Quick Learning and Fixed

Table 3
Pearson Correlations: Schommer's (1990) Epistemology Questionnaire

	QL	FA	CK	SK
Quick Learning	1.00	.46**	.28**	-.23**
Fixed Ability		1.00	.18*	-.11
Certain Knowledge			1.00	-.35**
Simple Knowledge				1.00

Note: *p<.05, **p<.01.

Ability (.46) suggests they may be measuring a similar, underlying construct.

Separate and Connected Knowing

The concepts of 'separate' and 'connected' knowing were first articulated in the work of Belenky, Clinchy, Goldberger, and Tarule (1986). Subsequent researchers have replicated the constructs and found them to be differentially related to decision making preferences (Ullman-Petrash, 1993), self-other differentiation, and integration (Woike, 1992, 1994; Lang-Takac & Osterweil, 1992). As well, research has shown that the 'separate' and 'connected' constructs differentially affect student overall satisfaction with, and overall performance in, post-secondary courses (Belenky et al., 1986; Clinchy, 1996). In addition, Buczynski (1993) developed a Ways of Knowing Scale based on Belenky et al.'s model. She reported exploratory and confirmatory factor analyses, and Cronbach Alphas, that supported the scale and its underlying constructs.

In a number of subsequent articles expanding on the 'separate' and 'connected' constructs, Clinchy (1989a, 1989b) describes the 'critical thinking' of the 'separate' knower (e.g., the propensity to use reasoned argument, and to think of differing or opposing trains of logic, when listening to another's point of view) as a key criteria distinguishing 'separate' from 'connected' knowing. She indicated that the following participant quote clearly tapped this distinction, and she noted she used the passage in the study described in the text, *Women's Ways of Knowing* (Belenky et al., 1986): "As soon as someone tells me about his/her point of view, I immediately start arguing in my head the opposite point of view. When someone is saying something, I can't help turning it upside down." (1989a, p.16).This passage was used in a similar fashion in the present study. That is, the passage was used as a prompt to tap separate and connected knowing in two settings: the participant's academic life and his/her personal life. The passage and prompts are provided in Appendix A.5 (Combined with the Waterman questions).

Waterman's (1982) Science Epistemology

Views of science were assessed using items drawn from Waterman's (1982) survey of science epistemology (see Appendix A.5). The survey was composed of thirty-three items pilot-tested with seventy-eight post-secondary biology students. During pilot interviews, the students were asked to interpret the survey items and to comment on item clarity. As well, the items were used to open discussion about the nature of Science knowledge. The student feedback, and that of graduate students in Science and a number of university faculty members, was used to revise the survey's items. Subsequently, two factor analyses found the expected three factor structure: Science knowledge and religious beliefs, a traditional view of Science, and a contemporary view of Science. Individual item loadings ranged from 0.3 to 0.55. The strength of these loadings may have been affected by the study's small sample size (i.e., 296 students).

The four items used in the present study were selected on the basis of 1) student ratings of item clarity and student accuracy in interpreting an item (both sources of information were provided in Waterman's study), and 2) high loadings (i.e., .3 to .55), relative to the remaining survey items, on Waterman's factor analyses. As in Waterman's study, the items were used to initiate "...discussion about the nature of science knowledge" (p. 56). The two contemporary view of Science items selected for the present study were the following: 1) Scientific knowledge is a changing and evolving body of concepts and theories, and 2) Theories and models are products of the human mind and may or may not accurately represent reality. The two items reflecting a traditional view of science knowledge were: 1) Scientific method will eventually let people learn the real truth about the natural world and how it works, and 2) The ultimate goal of science is to gather all the facts about natural phenomena. The items and their prompts are provided in Appendix A.5

Data Collection

The Eccles et al.'s (1982) scales and the Schommer (1990; 1994) Epistemology Questionnaire were prepared as a survey package and completed by all subjects. In addition to these instruments, the package contained a page requesting demographic information, an invitational letter describing the study, and a participant consent form (see Appendix B). The participants drawn from a university and a college were administered the packages in groups. The invitational letter and consent forms were read aloud by the examiner, and participants were reminded that there was no penalty if they chose to withdraw from the study. Shad Valley participants were contacted by mail and asked to complete and return the survey packages.

Once the survey packages were returned, a random sample of Shad Valley program graduates (16 females and 10 males) were interviewed by telephone. The interview participants were drawn from the Shad Valley group because, as previously noted, this group had talents, interests, and achievement in Science, which is the general field of interest in this study.

During the telephone interviews, the Waterman (1982) statements and the Ways of Knowing passage were verbally presented as prompts to access their approach to understanding knowledge and their views of science knowledge. The presentation of statements was counter-balanced so as to minimize the possibility of order effects.

Data Scoring

Research Instruments

Participant responses to the study's survey package were entered into a statistical program (i.e. Survey-Pro) which permitted a review of the study's data (e.g., response errors and omissions). Once the review was completed, the Survey-Pro program was used to convert the study's data into an SPSS data analysis file.

Interview Questions

As previously noted, the interview sample consisted of twenty-six Shad Valley program graduates (16 females and 10 males) randomly drawn from a pool of 1991-1995 participants in the Shad Valley program. Of the sixteen females interviewed, nine were majors in a Science discipline (i.e., math, physics, biology, chemistry, or engineering), and seven were majors in a nonscience discipline (i.e., arts, business, or computer). With respect to the ten males interviewed, six were majors in a Science (i.e., math, physics, biology, chemistry, or engineering), and four were nonscience majors (i.e., arts, business). Overall, fifteen of the participants interviewed were science majors and eleven were nonscience majors.

Separate and Connected Knowing. The participant's responses to the WWK passage were coded as being consistent with a 'separate' or 'connected' way of knowing, using definitions of 'separate' and 'connected' knowing (see Appendix C) from Belenky et al. (1986; 1997) and Clinchy (1989a; 1989b). By way of example, the participant responses noted below were coded as 'separate' and 'connected' ways of knowing, respectively:

> [interviewer reads the WWK passage : "As soon as someone tells me about his/her point of view, I immediately start arguing the opposite point of view. When someone is saying something, I can't help turning it upside down"]

Separate Knowing

Participant: "(laughter) yeah that's exactly what I do."

Interviewer: "Oh, is it?"

Participant: "Yeah (laughter). Like I don't know, I always think of the opposite and then it's uh, I don't agree with the opposite then I might agree with them, but I always build a case against what they say first." (Pharmacist major)

Connected Knowing

Participant: "[no]... I'm more likely to uhm...I guess empathize with the person's point of view and if I agree with it, then I won't uhm, I don't know, I rarely intentionally take the other side of an argument, just for the sake of doing that." (Biology major)

Once the initial set of responses were coded by this researcher, the coding process was repeated for the responses to prompts exploring the participants' ways of knowing in a personal setting.

Waterman's (1982) Science Epistemology. The coding of participant responses was guided by the definitions and guidelines provided by Waterman (1982). By way of example, participant responses that portrayed science knowledge as absolute (e.g., based on 'facts'), and additive in nature, were coded as 'Traditional' views of science knowledge. Responses that indicated science knowledge was 'fact,' but tentative and changing due to the limits of scientific method and/or human senses were coded as 'Modified-Traditional' views of science knowledge. Finally, interview responses that indicated science knowledge was probabilistic and constructed in nature (i.e., a product of the human mind) were coded as 'Contemporary' views of science knowledge. The following two participant quotes reflect 'Traditional' and 'Modified-Traditional' responses to the statement: Science knowledge is a changing and evolving body of concepts and theories.

'Traditional' view of science knowledge

> Participant: "Uhm, I think most of our major discoveries are already behind us, and now we're dealing with just putting the pieces together." (Science major)

'Modified-Traditional' view of science knowledge

> Participant: "there's no question. I guess I would say I would agree with that because uhm, obviously scientific knowledge is based on uh, certain premises that are, you know, determined by facts available at the time...I just think uhm, a lot of scientific knowledge is, is still growing, I mean there's not an absolute foundation of, of exact uh, answers out there I guess, at the moment, so I guess I would say it continually is evolving and in search for answers in a general sense I guess." (Film major)

The participant quote noted below represents a 'Contemporary' response to the statement: Theories and models of science are products of the human mind and may or may not accurately represent reality.

'Contemporary' view of science knowledge

> Participant: "Yeah, I completely agree with that. It's uhm, theories and particularly models are just something that we uhm, come up with to make uhm, to make what we observe easier for us to understand...I think that humans can only think about things in certain ways and it makes it so much easier for us to understand something if we can relate it to something we already know about like uhm, in the model of the atom there was a cookie dough model or something...it's easier for us to visualize and, of course uhm, it's sort of highly unlikely that the atom would be this way. (Biology major)

After participants' responses to statements were coded, the responses to the four Waterman statements were analyzed to obtain general classifications of the participants' views of science knowledge. Specifically, if three of the four responses were coded as a particular view (e.g., 'Modified-Traditional'), then the participant received the same classification (i.e., 'Modified-Traditional'). There were no cases where a participant obtained an even split between two views of science (e.g., two responses coded as a 'Traditional' view of science and two coded as a 'Modified-Traditional' view of science).

Reliability

An inter-rater check was performed on both the ways of knowing and science epistemology codes. Sixteen interview protocols (approximately sixty percent of the total interview sample) were randomly selected and independently coded by two raters. There was concurrence on all protocols for the ways of knowing codes (i.e., separate or connected across two contexts: the academic and personal setting), and concurrence on 15 of 16 protocols for the three views of science codes (i.e., 'Traditional', 'Modified-Traditional', or 'Contemporary'). The resulting inter-rater agreement was approximately 97% (31 of 32 protocols). Differences were resolved through discussion.

Data Analyses

For the purposes of data analyses, the variables Science Major and Science Favorite entailed the following range of disciplines: Math, Chemistry, Physics, Biology, and Engineering. The nonscience variables (i.e., Nonscience Favorite and Nonscience Major) included any discipline in the Arts (e.g., Sociology, History, Philosophy, English), or the fields of Business and/or Computers (e.g., public relations, human resources, multimedia development, programmer/analyst). The specific data analyses are outlined below. As an organizational aid, the various analyses are organized by research question.

Research Questions and Associated Statistical Analyses

1. **Is Schommer's (1990; 1994) Model of Epistemology related to Eccles et al's (1983; Eccles, 1987) Model of Achievement Motivation?**

This question was addressed by exploring Pearson Product Moment Correlations between Schommer's (1990, 1994) four epistemological beliefs and eight of Eccles et al.'s (1983; Eccles, 1987) constructs.

2. Do individuals who endorse a Science as a favorite subject differ from those who do not in terms of Schommer's (1990; 1994) epistemological beliefs and Eccles et. al's (1983; Eccles, 1987) constructs?

A MANOVA statistical analysis was used to determine whether there were differences between groups. This was followed by univariate F tests on several demographic variables. Subsequently, a Logistic Regression analysis was performed to determine which, if any, of the variables of interest predicted Science as a favorite subject.

3. Do participants who declare a Science as a major differ from those who do not in terms of Schommer's (1990; 1994) epistemological beliefs and Eccles et. al's (1983; Eccles, 1987) constructs?

A MANOVA statistical analysis and univariate F tests (on demographic variables) were performed to explore differences between groups. Subsequently, a Logistic Regression analysis was performed to determine which, if any, of the variables of interest predicted Science as a major.

4a. Do Schommer's (1990; 1994) epistemological beliefs and Eccles et. al's (1983; Eccles, 1987) constructs vary across gender?

4b. Do Schommer's (1990; 1994) epistemological beliefs and Eccles et. al's (1983; Eccles, 1987) constructs vary within gender?

A MANOVA was conducted to explore gender differences among the two sets of constructs. This analysis were followed by MANOVAS exploring differences between female students who chose a science versus nonscience subject as a favorite subject, and differences between female science majors versus nonscience majors.

5. Are there associations among Ways of Knowing, Science Epistemology, Gender, and declared Major?

Twenty-six sets of interview responses were coded as demonstrating either a 'separate' or 'connected' way of knowing, using definitions from Belenky et al. (1986, 1997) and Clinchy (1989a, 1989b). In addition, the interviews were coded as 'Traditional,' 'Modified-Traditional,' or 'Contemporary,' using Waterman's (1982) definitions noted in Chapter II. Once coding was completed, the question of associations was addressed by exploring: 1) the frequency of gender and major by Ways of Knowing, 2) the frequency of gender and major by Science Epistemology, and 3) the frequency of gender and major by Ways of Knowing and Science Epistemology.

CHAPTER IV

Results

This chapter presents a description of the participant sample followed by the analyses of the study's research questions. Each question is presented with the results of the analyses completed for that particular question.

Description of the Participants

One hundred and fifty-one undergraduate students participated in this study. Overall, the mean age of the students was 20.8 years (SD= 2.3), with a range of 18 to 35 years of age. Approximately half of the students were female (i.e., 58.7%), and the mean student grade point average (GPA) was 2.6 on a three point scale. In terms of parent education, a majority of the study's participants (i.e., 77%) indicated that their fathers had acquired a post-secondary education. As well, a majority of the participants (i.e., 68%) indicated that their mothers had obtained a post-secondary education.

The characteristics of individual participant groups were explored by descriptive statistics and compared by univariate F tests. As Table 4 illustrates, all three participant groups were significantly different in terms of age. An inspection of the participant surveys indicated that the difference in age among the groups was due to differences between the numbers of returning (i.e., mature) students in the Shad Valley group and in the group drawn from one post-secondary institution (a university), as well as few returning students in the group drawn from a secondary post-secondary group (a college).

Table 4
Participant Characteristics by Group

Source	Number of Subjects	Mean Age* (ranges)	Gender	Mean GPA** (3.0 Scale)
College	56	21.0 (18-35)	60% female	2.5
University	54	19.4 (18-22)	50% female	2.3
Shad	41	22.4 (20-26)	65% female	2.9

*Significant differences between all groups ($F(2,148) = 27.306$, $p < .01$).
**Significant difference between Shad vs College & University ($F(2,145) = 20.29$, $p < .01$).

A Scheffe post-hoc test revealed the Shad Valley group had a significantly higher GPA than did the University and College groups. This difference was not unexpected as the Shad Valley participants had a history of excelling in Math and/or Science. Further, a review of the literature indicated that GPA is not a primary predictor of the constructs in the present study (e.g., Schommer, 1988; Schommer & Donnell, 1994; Eccles & Jacobs, 1986).

An inspection of the levels of parent education across the three groups indicated that the university and the college groups had a lower percentage of fathers with a post-secondary education (i.e., 30% and 36%, respectively), and mothers with a post-secondary education (38% and 35%, respectively), than did the Shad Valley group (95% and 80%, respectively). Although there are differences in the level of parent education, a review of the literature indicated that the level of parent education is not a primary predictor of epistemological beliefs (e.g., Schommer & Dunnell, 1987) or Eccles et.al's (1983) constructs (e.g., Eccles, 1987; Jacobs & Eccles, 1992).

A review of the descriptive statistics on participants' declared major and discipline interests indicated there were significant differences among the three participant groups. The Shad Valley sample contained a majority of the Science majors and students with a Science as a favourite subject (44% and 49%, respectively). The samples drawn from the university and college contained few Science majors (26% and 30%, respectively), and few students with a Science as a favourite subject (20% and 31%, respectively). Additional group characteristics are provided in Appendix D. The implications of the group differences are discussed in the Delimitations and Limitations section of chapter IV.

Research Questions and Analyses

Question 1

Is Schommer's (1990; 1994) Model of Epistemology related to Eccles et al.'s (1983; Eccles, 1987) Model of Achievement Motivation?

A Pearson Correlation was conducted on Schommer's (1990; 1994) four epistemological beliefs and eight of Eccles et al.'s constructs. As Table 5 indicates, there were numerous significant correlations. A belief in Quick Learning was significantly and negatively associated with Expectation of Success, Self-Concept of Ability: Major, Self-Concept of Ability: Advanced, Utility: Courses, and both attainment values. A belief in Fixed Ability was significantly and negatively associated with Self-Concept of Ability: Advanced, Utility: Courses, and both attainment values. The belief Simple Knowledge was significantly and positively associated with Self-Concept of Ability (both Engineering and Advanced), Attainment Value: University, and both utility values.

A closer inspection of the Pearson Correlation output indicated the various significant correlations accounted for minimal variance. By way of example, the correlation between Attainment Value: University (ATVal:Univ) was statistically significant (i.e., -.37). However, the variance accounted for was only fourteen percent (i.e., 13.69 %). The low percentages of variance accounted for by the various significant correlations indicate the correlations have minimal practical import.

Table 5
Pearson Correlations: Schommer's (1990) and Eccles et al.'s (1983) Scales

	Exp[1]	SCA:M	SCA:E	SCA:AD	ATVal:M	ATVal:Un	Util:C	Util:J
QL	-.21*	-.27**	-.15	-.174*	-.25*	-.33**	-.19*	.08
FA	-.14	-.16	-.06	-.17*	-.22*	-.37**	-.23**	-.00
SK	.12	.08	.33**	.29**	.01	.24**	.26**	.25**

[1]Expectation of Success, Self-Concept of Ability: Major, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, Attainment Value: Major, Attainment Value: University, Utility: Courses, Utility: Job, Quick Learning, Fixed Ability, Simple Knowledge. Note: N = 151, *p<.05, **p<.01

Question 2

Do individuals who endorse a Science as a favourite subject differ from those who do not in terms of Schommer's (1990; 1994) epistemological beliefs and Eccles et al.'s (1983; Eccles, 1987) constructs?

A MANOVA indicated significant differences between those who did or did not declare a Science as a favourite subject (Hotellings $T^2 = .45$, $F = 6.9$, $p < .001$). Table 6 presents the univariate results. As the table illustrates, those who indicated a Science was a favourite subject had significantly higher mean endorsements on Expectation of

Success, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, and Fixed Ability, and a significantly lower endorsement on Utility: Job.

Table 6
Science as a Favourite Subject: Group Differences on Key Variables

	Science not a favourite N = 83		Science as a favourite N = 65		Univariate F Total N = 148
Variable[1]	Mean	S. Deviation	Mean	S. Deviation	
Exp.of Su	**15.86**	**3.42**	**18.03**	**2.57**	**10.64****
SCA:Eng	**18.39**	**6.30**	**26.87**	**6.17**	**43.64*****
SCA:Adv	**10.36**	**2.74**	**11.47**	**1.98**	**4.29***
Value:Univ	14.77	3.22	14.63	4.11	0.39
Utility:Job	**3.69**	**0.94**	**3.30**	**0.65**	**4.72***
Utility:Crs	9.84	2.50	10.23	2.40	.60
Quick Lrn	20.79	4.55	20.73	3.74	.00
Fx Ability	**31.56**	**5.30**	**34.17**	**5.46**	**5.73***
Sim.Know	56.53	7.09	58.63	6.65	2.15

[1]Expectation of Success, Self-Concept of Ability:Engineering, Self-Concept of Ability:Advanced, Attainment Value:University, Utility:Job, Utility:Courses, Quick Learning, Fixed Ability, Simple Knowledge. Note: *p <.05, **p <.01, ***p <.001.

ANOVAS on demographic variables indicated that there were significant differences between the Science favorite and nonscience favorite groups in terms of Age (F=17.0, p<.001) and GPA (F=9.2, p<.01). Participants who listed a Science as a favourite subject were significantly older (mean = 22.3, S.D.= 2.2) than those who did not list a Science as a favourite subject (mean = 20.4, S.D.= 2.4). As well, participants who indicated a Science as a favourite subject reported a significantly higher GPA (mean = 2.8, S.D.= 0.6) than did those who did not indicate a Science as a favourite subject (mean = 2.4, S.D.= 0.6). Further, there were higher percentages of fathers with a post-secondary education in the group indicating a science as a favourite (73.3%) than in the group not indicating a Science as a favourite (28.6%). The findings were similar for mothers with a post-secondary education (46.7% and 28.6%, respectively).

Because the variables in the present analyses were a mix of continuous and dichotomous variables, a Logistic Regression analysis was performed to determine which of the variables noted above predicted science as a favourite subject (Tabachnick & Fidell, 1996). As part of the analysis, a Wald statistic is generated and reported (see Table 7). Tabachnick and Fidell (1996) indicate this statistic is the equivalent to a univariate F statistic.

As Table 7 illustrates, three variables were significant predictors. These were: Self-Concept of Ability: Engineering, Fixed Ability, and Age. The logistic regression equation correctly classified sixty percent of the participants who did endorse a Science as a favourite subject, and correctly classified ninety-five percent of whose who did not make such an endorsement. The overall percentage classified correctly was approximately ninety percent (i.e., 87.67%). These classification estimates may be inflated as they incorporate significantly different percentages of students with a science as a favorite subject and a nonscience as a favorite subject (i.e., 56%, and 44%, respectively).

Table 7

Science as a Favourite Subject: Logistic Regression Analysis

Variable[1]	Beta Weight	R	Wald[2]
Exp.of Su	.03	.00	.14
SCA:Eng	**.23**	**.26**	**12.77****
SCA:ADV	-.17	.00	1.42
Utility:Job	-.74	-.09	3.30
Utility:Crs	-.14	.00	.98
Quick Lrn	-.05	.00	.26
Fx Ability	**.12**	**.14**	**5.41***
Sim.Know	-.01	.00	.00

[1]Expectation of Success, Self-Concept of Ability:Engineering, Self-Concept of Ability:Advanced, Attainment Value:University, Utility:Job, Utility: Courses, Quick Learning, Fixed Ability, Simple Knowledge, Gender, Age, and Grade Point Average.
[2] The Wald statistic is the equivalent of a univariate F statistic (Tabachnick & Fidell, 1996). *p<.05, **p =.01.

Question 3

Do individuals who declare a Science as a major differ from those who do not in terms of Schommer's (1990; 1994) epistemological beliefs and Eccles et al.'s (1993; Eccles, 1987) constructs?

A MANOVA indicated significant differences between those who did or did not elect a Science major (Hotellings $T^2 = 1.08$, $F = 8.86$, $p < .001$). Table 8 presents the univariate results. As the table illustrates, those who indicated a Science major had significantly higher mean endorsements on Expectation of Success, Self-Concept of Ability: Major, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, Utility: Courses, and Simple Knowledge.

ANOVAS on the demographic variables indicated that there was a significant difference between the groups in terms of age ($F = 32.2$, $p < .001$). Science majors were older (mean = 22.3, S.D.= 2.3), than nonscience majors (mean = 20.2, S.D.=1.5). Differences between the groups in terms of GPA approached significance ($F = 3.7$, $p < .059$). Science majors tended to have a higher GPA (mean = 2.7, S.D.=.5) than did nonscience majors (mean = 2.5, S.D.=.6). Further, there were higher percentages of fathers with a post-secondary education in the group indicating a science major (70%) than in the group not indicating a science major (32%). Similar results were obtained for mothers with a post-secondary education (41% and 32%, respectively).

Table 8
Science Major: Group Differences on Key Variables

	NonScience Major N = 38		Science Major N = 27		Univariate F Total N = 65[2]
Variable[1]	Mean	S. Deviation	Mean	S. Deviation	
Exp.of Su	**16.07**	**3.34**	**17.76**	**2.55**	**7.67****
SCA:M	**15.32**	**2.94**	**16.67**	**2.65**	**5.64***
SCA:Eng	**16.80**	**5.16**	**26.93**	**5.74**	**86.73*****
SCA:Adv	**10.30**	**2.29**	**11.60**	**2.26**	**7.96****
AtValue:M	22.90	3.46	24.17	3.12	3.59
AtValue:Univ	14.77	3.40	15.40	3.59	.32
Utility:Job	3.63	0.96	3.55	0.83	.22
Utility:Crs	**9.78**	**2.62**	**10.83**	**2.11**	**4.63***
Quick Lrn	21.50	4.58	19.93	4.23	3.09
Fx Ability	32.38	5.20	32.60	5.47	.039
Sim.Know	**55.92**	**6.86**	**60.24**	**6.93**	**9.72****

[1]Expectation of Success, Self-Concept of Ability: Major, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, Attainment Value, Attainment Value:University, Utility: Job, Utility: Courses, Quick Learning, Fixed Ability, Simple Knowledge. [2]The N of 65 majors represents 44% of the overall sample N (i.e., 148). Note: *p <.05, **p <.01, ***p <.001.

As previously noted, due to the mixed nature of the independent and dependent variables (i.e., continuous and discrete), a Logistic Regression analysis was performed to determine which, if any, of the variables noted above predicted Science as a major. As Table 9 illustrates, Self-Concept of Ability: Engineering, Fixed ability, and Age were significant predictors of Science as a major. The logistic regression equation classified correctly seventy-three percent of the participants who elected a Science major, and classified correctly ninety-four percent of those who did not elect a Science as a major. The overall percentage classified correctly was ninety percent (i.e., 89.22 %). As previously noted, these estimates may be inflated due to the significantly different percentages of nonscience and science majors (i.e., 58% and 42%, respectively; N = 65).

Table 9
Science Major: Logistic Regression Analysis

Variable[1]	Beta Weight	R	Wald[2]
Exp.of Su	-.03	.00	.20
SCA:Major	.10	.00	.25
SCA:Eng	**.37**	**.32**	**13.27****
SCA:Adv	-.16	.00	.45
AtValue: Major	-.12	.00	.88
AtValue:Univ	-.08	-.05	.46
Utility:Job	-.60	.00	.27
Utility:Courses	-.21	.00	1.59
Quick Lrn	-.10	.00	.20
Fx Ability	**.18**	**.15**	**4.32***
Sim.Know	-.05	.00	1.02

[1]Expectation of Success, Self-Concept of Ability: Major, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, Attainment Value: Major, Attainment Value: University, Utility: Job, Utility: Courses, Quick Learning, Fixed Ability, Simple Knowledge, Gender, Age, and Grade Point Average. [2] The Wald statistic is the equivalent of a univariate F statistic (Tabachnick & Fidell, 1996). Note: *p <.05, **p <.01.

Question 4a

Do Schommer's (1990; 1994) epistemological beliefs and Eccles et al.'s (1983; Eccles, 1987) constructs differ across gender?

A MANOVA was conducted to explore gender differences among two sets of constructs: epistemological beliefs and Eccles' (Eccles et al., 1983) scales. As Table 10 illustrates, there are significant gender differences (Hotelling's $T^2 = .21$, $F = 3.35$, $p < .01$). Female participants had significantly higher mean endorsements on Attainment Value: University (mean = 15.28, S.D.= 2.93), relative to males (mean = 13.76, S.D.= 3.91). Male participants had significantly higher mean endorsements on Quick Learning (mean = 22.23, S.D.= 4.81), relative to similar, female participants (mean = 20.10, S.D.= 4.23), and they had significantly higher mean endorsements of Fixed Ability (mean = 33.35, S.D.= 5.54), as compared to similar, female participants (mean = 31.43, S.D.= 5.27). As well, on the variable Self-Concept of Ability: Engineering, which approached significance (i.e., $p = .051$), male participants tended to have a higher mean of endorsement (mean = 21.32, S.D.= 6.70) than did female participants (mean = 19.00, S.D.= 7.43).

Table 10
Gender Differences: Epistemological Beliefs and Eccles' (1983) Scales

	Male Participants ($N=59^2$)		Female Participants (N=89)		
Variable[1]	Mean	S. Deviation	Mean	S. Deviation	Univariate F Total N = 148
Exp.of Su	16.02	3.32	16.43	3.38	.60
SCA:Eng	**21.32**	**6.70**	**19.00**	**7.43**	**3.87**[3]
SCA:Adv	10.47	2.70	10.60	2.59	.09
AtValue:Univ	**13.76**	**3.91**	**15.28**	**2.93**	**7.48****
Utility:Job	3.77	1.06	3.52	.76	3.01
Utility:Crs	9.65	2.40	10.03	2.53	.90
Quick Lrn	**22.23**	**4.81**	**20.10**	**4.23**	**8.23****
Fixed Ability	**33.35**	**5.54**	**31.43**	**5.27**	**4.69***
Sim.Know	55.87	7.87	57.54	6.28	2.10

[1]Expectation of Success, Self-Concept of Ability:Engineering, Self-Concept of Ability:Advanced, Attainment Value:University, Utility:Job, Utility: Courses, Quick Learning, Fixed Ability, Simple Knowledge. [2] Three male protocols were incomplete. Note: [3]$p = .051$, *$p < .05$, **$p < .01$.

MANOVAS exploring gender differences within the major and favourite subject groups were nonsignificant.

Question 4b

Do Schommer's (1990; 1994) epistemological beliefs and Eccles et al.'s (1983; Eccles, 1987) constructs vary within gender?

A MANOVA was performed to explore differences between female subjects who selected a Science as a favourite subject and those who did not, and between female subjects with a Science major and those with a nonscience subject as a major. The results were significant for the Science favourite group (Hotellings T^2 =.48, F = 4.20, $p<.001$) and the Science major group (Hotellings T^2 =1.03, F = 4.50, $p<.001$).

Table 11 presents the univariate results for the science favourite group. As the table illustrates, female students who selected a science as a favourite subject had a higher mean endorsement on several Eccles et al.'s constructs (i.e., Expectation of Success, Self-Concept of Ability (Eng, Adv,) and Utility: Courses) relative to female students who chose a subject other than a Science as a favourite subject. These groups did not differ in terms of intrinsic task values. Additionally, female students with a Science as a favourite subject had a significantly stronger belief in Fixed Ability than did students who chose a subject other than a Science as a favourite subject.

Table 11

Science Favourite: Differences Among Female Students on Key Variables

	NonScience Favourite N = 52		Science Favourite N = 37		MANOVA F Total N = 89
Variable[1]	Mean	S. Deviation	Mean	S. Deviation	
Exp.of Su	**15.97**	**3.37**	**19.00**	**2.15**	**10.42****
SCA:Eng	**17.57**	**6.54**	**27.43**	**5.79**	**27.64*****
SCA:ADV	**10.38**	**2.66**	**11.93**	**1.73**	**4.37****
AtValue:Univ	15.30	2.88	15.43	3.27	.02
Utility:Job	3.53	0.74	3.50	0.85	.02
Utility:Crs	**10.04**	**2.58**	**10.14**	**2.41**	**.02***
Quick Lrn	19.99	4.11	19.86	3.94	.01
Fx Ability	**30.76**	**5.07**	**34.29**	**5.06**	**5.71***
Sim.Know	57.16	6.54	60.07	3.83	2.59

[1]Expectation of Success, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, Attainment Value:University, Utility: Job, Utility: Courses, Quick Learning, Fixed Ability, Simple Knowledge. Note: *p <.05, **p <.01, ***p <.001.

Table 12 presents the univariate results for the Science major group. As the table illustrates, female Science majors had significantly higher mean endorsements of Self-Concept of Ability (Eng, Adv), relative to nonscience majors. In addition, they had a significantly higher mean endorsement of Simple Knowledge, relative to nonscience female majors. There were no differences between Science and nonscience majors in terms of Expectation of Success, Utility: Courses, or Fixed Ability; constructs that distinguished between females with a Science or nonscience subject as a favourite subject.

Table 12

Science Major: Differences Among Female Students on Key Variables

	NonScience Major N = 23		Science Major N = 17		Univariate F Total N = 40[2]
Variable[1]	Mean	S. Deviation	Mean	S. Deviation	
Exp.of Su	15.91	3.51	18.09	2.39	2.60
SCA:Eng	**16.67**	**6.09**	**26.55**	**5.70**	**41.10****
SCA:ADV	**10.15**	**2.72**	**12.05**	**1.43**	**5.84***
AtValue:Univ	15.05	2.82	16.14	3.15	2.41
Utility:Job	3.48	0.73	3.64	0.85	.65
Utility:Crs	9.83	2.50	10.73	2.59	1.43
Quick Lrn	20.27	3.88	19.05	4.54	2.11
Fx Ability	30.79	5.02	32.91	5.53	.88
Sim.Know	**56.47**	**6.29**	**61.09**	**4.84**	**6.80***

[1]Expectation of Success, Self-Concept of Ability: Engineering, Self-Concept of Ability: Advanced, Attainment Value:University, Utility: Job, Utility: Courses, Quick Learning, Fixed Ability, Simple Knowledge. [2]Less than half (i.e., 45%) of all females had selected a major (the percentage for males was 46%). Note: *p <.05, **p <.001.

Question 5

Are there associations among Ways of Knowing, Science Epistemology, Gender, and Major?

Two frequency-based analyses were conducted. The first compared the Ways of Knowing and declared major of the twenty-six Shad Valley interview participants. As Figure 1 illustrates, there is a trend among the sixteen female participants. All six female participants with a 'separate' way of knowing in both academic and personal settings had a Science as a major. Of those six female participants with a 'separate' way of knowing in an academic setting and a 'connected' way of knowing in a personal setting, two had a Science major. Finally, of the four female participants with a 'connected' way of knowing across academic and personal settings, one had a Science major. In contrast, nine of the ten male participants with a 'separate' way of knowing in both academic and personal settings had a mix of majors (i.e., 5 Science and 4 nonscience). The single male participant with a 'separate' way of knowing in an academic setting and a 'connected' way of knowing in a personal context had a Science major.

The second frequency-based analysis compared Science Epistemology (i.e., views of science knowledge), gender, and major. As figure 2 illustrates, most participants, regardless of gender, had a 'Modified-Traditional' view of Science knowledge. The numbers of 'Traditional' and 'Contemporary' views were quite small (i.e., four per category), precluding analysis of gender differences among the three views of science, and comparisons among views of science, Ways of Knowing, gender, and major.

Ways of Knowing by Major (Female Participants)

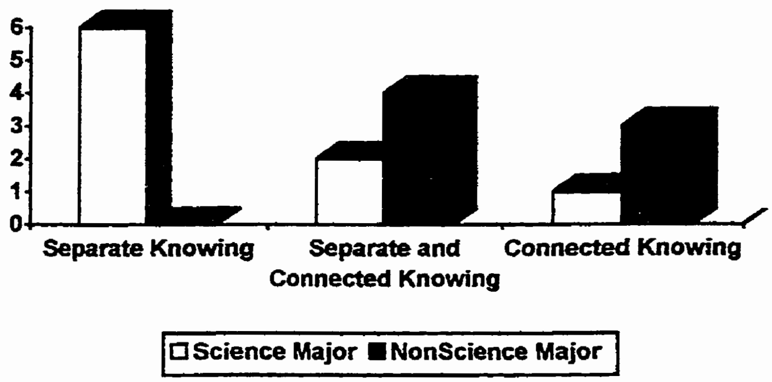

Figure 1. Frequencies of Ways of Knowing by Major

Views of Science Knowledge by Gender

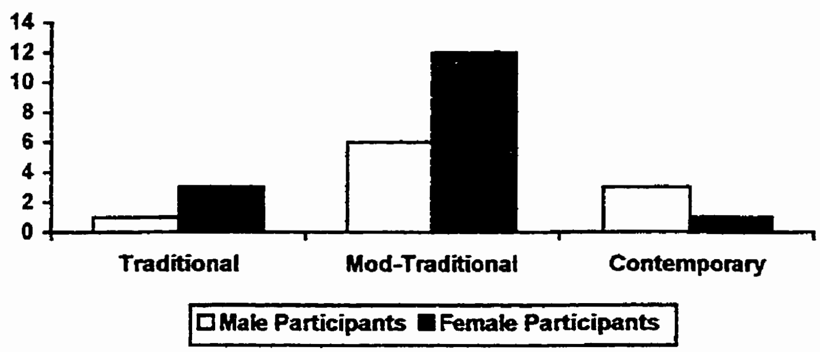

Figure 2. Frequencies of Views of Science Knowledge by Gender

CHAPTER V

Discussion

This chapter begins with a discussion of the study's results as they pertain to each research question. Following this is a general discussion of the study's findings. The subsequent sections in this chapter discuss the limitations of the current study and directions for future research.

Research Questions

1. **Is Schommer's (1990; 1994) Model of Epistemology related to Eccles' (Eccles et al., 1983; Eccles, 1987) Model of Achievement Motivation?**

The results of the present study indicate that there were significant statistical relationships between the two models. However, the variance accounted for in these relationships, and therefore their practical import, was minimal. This may reflect a lack of association between the models and/or the psychometric properties of Schommer's (1990; 1994) scale. The impact of the scale's properties on the findings of the current study is discussed further in the Delimitations and Limitations and Directions for Further Research sections of this chapter.

2. **Do participants who endorse a Science as a favorite subject differ from those who do not in terms of Schommer's (1990; 1994) epistemological beliefs and Eccles' (Eccles et al., 1983; Eccles, 1987) constructs?**

Students with a Science as a favorite subject had a higher self-concept of ability in regards to Engineering, Math, and Science, as well as a higher expectation of success and a stronger belief in fixed ability than did students with a nonscience as a favorite subject.

As well, students with a Science as a favorite subject had a higher self-concept of ability, in terms of completing an advanced degree, and they placed less emphasis on the employment value of attending university (i.e., a lower endorsement of Utility: Job).

There were several differences between the Science and nonscience favorite subject groups that predicted choice of a Science as a favorite subject. These included: Self-Concept of Ability in Engineering, Math, and Science, and a belief in Fixed Ability. Among demographic variables, age, but not GPA or gender, predicted Science as a favorite subject.

These results suggest that Self-Concept of Ability: Engineering predicts post-secondary student assignment of Science as a favorite subject. This is consistent with Eccles' previous work involving similar scales, secondary students, and the choice of a particular academic course (Eccles et al., 1983; Eccles, 1984; Eccles, 1987).

Of particular interest in the current study is the finding that expectation of success distinguished between, but did not predict, differences between students with a Science or a nonscience as a favorite subject. Further, numerous task values (i.e., Attainment Value: University, and Utility: Courses) failed to predict differences between participants in the favorite subject group. Eccles, however, has found that, at the secondary school level, expectation of success and subjective task values were predictive of student academic choices (Eccles et al., 1983; Eccles, 1984).

The difference between Eccles' (Eccles et al., 1983; Eccles, 1987) research and the current findings suggests that Eccles' constructs may operate differentially (i.e., vary in relative importance) when considering student interests and student academic choices at the post-secondary level of education. It may be that, in terms of student academic interests, self-concept of ability appears to be relatively more important than expectations of success, the intrinsic value assigned to university, or the utility values assigned to specific university courses and to university, in general. Student interests may be primarily guided by what they believe they are good at, rather than by their expectations and subjective task values. The impact of Eccles' constructs on student interests and choices at different education levels is an area for further research.

Additional factors not explored by Eccles at the secondary level, but that appear to predict interest in a subject (i.e., a Science as a favorite subject) were a belief in learning (Fixed Ability), and the demographic variable, age. Relative to students with a nonscience subject as a favorite subject, students with a Science as a favorite subject were older and had a stronger belief in the immutability of one's ability to learn. Although speculative, these differences may reflect greater or longer exposure to pedagogical practices (e.g., in Science) that encourage students to rely on rote memory to master compendiums of discipline-related 'facts' presented through the early course of their undergraduate education. Their success may encourage a stronger belief in the importance of rote memory (i.e., their natural ability), and thus foster a greater belief in a fixed ability to learn.

3. **Do participants who declare Science as a major differ from those who do not in terms of Schommer's (1990; 1994) epistemological beliefs and Eccles' (1983; Eccles, 1987) constructs?**

Science majors had higher Expectations of Success and Self-Concept of Ability (Major; Engineering, Math, Science; Advanced) than did nonscience majors. As well, they held a stronger belief in Simple Knowledge, and they perceived more utility in their courses than did nonscience majors. Additional analysis indicated that Self-Concept of Ability: Engineering, Fixed Ability, and Age, variables that predicted Science as a favorite subject, also predicted Science as a major.

These results are consistent with Eccles' (Eccles et al., 1983; Eccles, 1984) previous findings regarding the predictive relationship between self-concept of ability and choosing a particular subject in secondary school populations. It appears that this relationship holds for post-secondary students' choice of major. Interestingly, although Eccles found that subjective task values and expectation of success have a predictive relationship with achievement-related choices in a secondary school setting, the current study did not find a predictive relationship between these values, expectations, and choice of a Science or nonscience major. This may suggest that these constructs are relatively less important than self-concept of ability (in Engineering, Math, and Science) when students are committing to a major in a Science. However, when considering individual courses, these constructs may gain relative importance and predictiveness, as demonstrated in Eccles' previous work (e.g., Eccles et al., 1983; Eccles, 1987; 1994). The difference in relative importance in the roles of Eccles' constructs in predicting a major and course selection is an area for further study.

4(a) Do Schommer's (1990; 1994) epistemological beliefs and Eccles' (Eccles et al., 1983; Eccles, 1987) constructs vary across gender?

The results of the present study suggest that there were significant gender differences among the sets of constructs. Female participants assigned a higher intrinsic value to university than did their male counterparts. As well, they had a stronger belief in being able to improve their ability to learn (i.e., lower endorsement of Fixed Ability), and a stronger belief that their learning is a gradual process (i.e., a lower endorsement of Quick Learning) than did their male counterparts. In addition, female students, relative to their male counterparts, tended to have a lower self-concept of ability in the fields of Engineering, Math, and Science. These gender differences are consistent with existing literature (Eccles, 1987; Schommer, 1994).

4b) Do Schommer's (1990; 1994) epistemological beliefs and Eccles' (Eccles et al., 1983; Eccles, 1987) constructs vary within Gender?

An analysis of within gender differences revealed female students with an interest in a Science had a higher self-concept of ability in Engineering, Math, and Science, and in acquiring advanced degrees, than did female students with a nonscience favorite. A similar pattern was found between female students with a Science major and those with a nonscience major.

There were a number of inconsistencies across the favorite subject and major groups. Female students with a Science as a favorite subject, relative to female students with a nonscience as a favorite, had a stronger expectation of success, and stronger beliefs in the utility of their courses and in a fixed ability to learn. However, among female Science and nonscience majors, there was no difference in terms of expectations of success, course utility or belief in fixed ability. Rather, female Science and nonscience majors were differentiated by a belief in Simple Knowledge. That is, female Science majors, relative to female students with a nonscience major, had a significantly stronger belief in the simple, encyclopedic nature of knowledge.

5. Are there associations among Ways of Knowing, Science Epistemology, Gender, and Major?

The results of the present study indicated that the 'separate' and 'connnected' knowing constructs were associated with gender. Specifically, twelve of the sixteen female participants interviewed in the present study used a 'separate' way of knowing, whereas nine of ten males interviewed indicated a 'separate' way of knowing.

An interesting trend was found when comparing Ways of Knowing, gender, and major. All six female participants with a 'separate' way of knowing in both an academic and personal setting were Science majors. Two of six female participants with a 'separate' way of knowing in an academic context and a 'connected' way of knowing in a personal context were Science majors, and only one of three females with a 'connected' way of knowing in both an academic and personal setting was a Science major (see Figure 1). In contrast, there was a balance of Science and nonscience majors among the nine male participants with a 'separate' way of knowing in both an academic and personal setting.

This trend of increasing 'separateness' and increasing selection of a Science as a major is consistent with, and may provide additional evidence of, the posited conflict women experience as they are exposed to a 'separate' way of knowing in university. The literature indicates that Science is particularly empiricist and 'separate' in its pedagogical practices at the undergraduate level (e.g., Edmonton & Novak, 1993). It may be that the posited conflict generated by the pedagogical demand to shift from a 'connected' to a 'separate' way of knowing is exacerbated by the particularly strong empiricist and separate pedagogical practices used in undergraduate Science courses. This aggravated conflict may be an additional factor contributing to female students' tendency to pursue majors and careers in fields other than Science.

With respect to Science Epistemology, the results of the present study indicate that students hold perceptions of Science knowledge that are consistent with a 'Traditional,' 'Modified-Traditional,' or 'Contemporary' view of Science knowledge. A majority of this study's interviewed participants (eighteen of the twenty-six interviewed participants) held a 'Modified-Traditional' view of Science knowledge. That is, they viewed Science knowledge as discovered, based on observeable, absolute facts, but tentative and changeable due to the limitations of the scientific method and/or human senses. Four of the twenty-six interviewed participants held a 'Traditional' view of Science knowledge. They viewed Science knowledge as discovered, based on absolute, observable facts, and additive rather than tentative in nature. Finally, four of the twenty-six participants interviewed held a 'Contemporary' view of Science knowledge. That is, they viewed Science knowledge as products of the human mind (i.e., constructed rather than discovered) and thus probabilistic rather than absolute in nature.

The distribution of views of Science among participants in the current study (i.e., the presence of a large majority of 'Modified-Traditional' views of Science) is consistent with Waterman (1982) who found that a large majority of her participants had a

'Modified-Traditional' view of Science knowledge. Unfortunately, the presence of relatively few 'Traditional' or 'Contemporary' views of Science knowledge precluded exploring relationships between views of Science Epistemology, Women's Ways of Knowing, gender, and major.

General Discussion

The current study explored the tendency of female students to pursue advanced courses and/or a careers in fields other than Math and Science, though they are as capable as male students in these domains. This question of female persistence in Science, which is defined in this study as involving two elements: an interest in and the selection of a major in a Science, was explored by 1) examining relations between Schommer's (1990; 1994) Model of Epistemology and Eccles' (Eccles et al., 1983; Eccles, 1987) Model of Achievement Motivation, and 2) exploring associations between approaches to knowing, views of Science knowledge, commitment to a Science major, and gender.

The present study found that beliefs about the nature of learning and the nature of knowledge predict and/or are associated with interest in and commitment to a Science. Further, the observed differences in the roles that these beliefs and Eccles'(Eccles et al., 1983; Eccles, 1987) constructs play in student interest in and/or commitment to a major in Science provides an indication of the dynamic processes involved in persisting in an academic subject at the undergraduate level of education.

The findings of the present study suggest that there are a number of individual differences among and between the participant groups. Expectations of Success and Self-Concept of Ability (Engineering and Advanced) consistently distinguished between a) students who had an interest in Science and students with an interest in a nonscience subject, and b) between students who elected a major in Science or a field other than a Science. Students with a Science as a favorite subject had higher expectations of success at university and a higher self-concept of ability in Engineering, Math, and Science, and in acquiring advanced courses in these subjects than did students with a nonscience as a favorite subject. Moreover, students with a major in Science were higher on these constructs than were students with majors in a nonscience subject. These findings are consistent with the literature on Eccles' model and its application at the secondary school level (e.g., Eccles et al., 1983; Eccles, 1987). The present findings contribute to this body of literature by suggesting Eccles' model is predictive at the undergraduate level of education.

Of particular interest are the inconsistencies among the variables distinguishing between students with an interest in, or a commitment to, Science and students with interests and commitments to subjects other than Science. Specifically, students who indicated Science as a favorite subject had a significantly lower endorsement of the usefulness of attending university to improve employment prospects (i.e., Utility: Job), than did students with a nonscience subject as a favorite subject. Additionally, students with a Science major, relative to nonscience majors, had a significantly higher endorsement of the usefulness of courses in meeting the demands of a major and/or career (i.e., Util: Crs). There was no difference between Science and nonscience majors in terms of the usefulness of attending university to improve employment prospects (i.e., Util: Job). Although speculative, the inconsistencies in the utility value endorsements noted above may suggest that once students move from having an interest in, to committing to, Science (reflecting persistence in the subject) their perceptions of the utility value of university and discipline-related courses may increase to a greater degree than is the case for students committing to nonscience majors. Why this may occur is an area for further research.

In addition to the differences among Eccles' variables across the favorite subject and major groups, there were differences in the relative importance of various epistemological beliefs. Students who indicated Science as a favorite subject had a stronger belief in a fixed ability to learn than did those students who indicated a nonscience subject as a favorite. Science majors had a stronger belief in the simplicity of knowledge (i.e., knowledge is absolute and encyclopedic in nature) than did nonscience majors. Although speculative, the relative differences in the role of epistemological beliefs may reflect student adjustment to academic commitments. For example, once a student commits to a major in Science, s/he may begin to place less emphasis on the ability to learn and more emphasis on acquiring knowledge in the domain.

There were a number of gender-related findings in the present study, although these differences were not as strong as the differences between individuals noted above. Female students assigned a higher intrinsic value to university than did their male counterparts. As previously note, in the present study, neither intrinsic value nor utility values predicted commitment to Science. These findings expand the current literature on Eccles' (1987) model in that Eccles' earlier work with secondary students indicated task values accounted for gender-related patterns of course selection. The present findings suggest values do not appear to predict post-secondary student interest in, or commitment to, Science.

In addition to differences in values, female participants, relative to their male counterparts, had a significantly lower endorsement of beliefs in Fixed Ability, Quick Learning, and Self-Concept of Ability (Engineering). As previously reported, Fixed Ability and Self-Concept of Ability (Engineering) were found to be predictors of interest in, and commitment to, Science. The individual and aggregate influences these constructs have on female and male interest in, and/or commitment to, Science are areas for further study.

An analysis of within gender differences revealed some interesting consistencies and differences among female students. In the favorite subject group, female students with Science as a favorite subject had significantly higher Expectations of Success and Self-Concept of Ability (Engineering; Advanced) than did female students endorsing a nonscience favorite. Self-Concept of Ability (Engineering; Advanced), but not Expectations of Success, similarly distinguished between female Science and nonscience majors. The differences in Expectation of Success among female students in the present study is an interesting area for further research.

The individual and gender differences found across Eccles' (1983) constructs furthers the literature on her model of achievement motivation. As previously noted, the literature on this model has involved secondary students and their achievement-related choices or adults and their career choices. There is little research available on how the model may work in undergraduate populations. The present study found that Eccles'

(Eccles et al., 1983; Eccles, 1987) model holds for students at the undergraduate level of education, a time of important decisions regarding pursuing advanced education and/or a career in a particular academic field. As well, the results of the present study found that the model's constructs work in a more complex fashion than previously indicated in the literature.

Previous research has found that expectations of success, perceptions of ability, and subjective task values (intrinsic value more so than utility value) predicted secondary student academic choices (e.g., Eccles et al., 1983; 1984; Eccles, 1987; 1994). In the undergraduate student population in this study, these constructs appear to operate in a complex manner. Neither expectations of success nor task values predicted student interest in, or commitment to, Science. Among female students, those with a Science as a favorite subject had significantly higher Expectations of Success than did females with a nonscience favorite subject. Female Science and nonscience majors had similar levels of Expectation of Success.

With respect to subjective task values, among female students, the utility value of courses was significantly higher for female students with a science as a favorite subject, relative to those with a nonscience favorite subject. However, utility values (i.e., Course or Job) did not distinguish between female Science and nonscience majors. The construct, Attainment Value: University, was higher for males than for females, in general, but it did not predict interest in, or commitment to, Science. The present study's findings indicate neither attainment or utility values in general predict interest in, or commitment to, Science.

The most consistent predictor of student interest in, and/or commitment to, a discipline was Self-Concept of Ability in the areas of Engineering, Math, or Science. In terms of individual differences, perceptions of ability in the areas of engineering, math, or Science were higher for individuals with interests in, or commitment to, a Science, as compared to students with interests and commitments in areas other than Science. With respect to gender, perceptions of ability were higher for males than females, in general. Among female students, perceptions of ability were higher for females with interests in, or commitment to, a Science. These findings suggest that Self-Concept of Ability in the areas of Engineering, Math, and Science is a consistent marker of interest in and/or commitment to Science.

The current findings regarding task values contribute to the literature on Eccles' (Eccles et al., 1983; Eccles, 1987) model. Previous research by Eccles indicated that task values (i.e., Attainment and Utility values) predict gender differences in course selection (e.g., Eccles, 1984; Eccles, 1987). In the present study, the intrinsic value assigned to university was significantly higher among female students than among male students. However, intrinsic value did not predict interests or majors. The second value measured, Utility value (Courses, Job), differentiated between student academic interests and majors, but did not predict Science major or interest in Science. Although speculative, these findings suggest that when students move from an interest in Science to a commitment to Science, the intrinsic value assigned to Science becomes relatively less important than utilitarian or practical considerations relating to the chosen major. The shift in the relative importance of task values, across student interests and commitments, is an area for further research.

The present findings make a number of contributions to our understanding of epistemology. There is further evidence of the independence of Schommer's (1990; 1994) constructs in that there is variation among beliefs within and across the Science favorite and Science major groups. There is variation in terms of which beliefs distinguish between, and/or predict, Science as a favorite subject and Science as a major. Further, this variation extends to differentiating between female and male students, in general, and between female students within the Science as favorite subject and Science major groups. Specifically, female students, in general, had a significantly lower endorsement of beliefs in Quick Learning and fixed ability, relative to male students, and female students with interests in, or a commitment to, a Science, relative to their female nonscience counterparts, had a stronger endorsement of fixed ability and simple knowledge, though still lower than those endorsements of male participants.

An examination of the variability of epistemological beliefs suggests there may be a shift in the relative importance of these beliefs when considering students' interests in, and their commitment to a major in, a Science. Although speculative, if one describes the movement from interest to commitment as persistence, then underlying this persistence is a shift in epistemological positions. Students may move from an position that highlights beliefs about learning to a position that highlights beliefs about knowledge, as they persist in Science. Interestingly, in addition to this shift, there is an increase in the strengths of these beliefs, suggesting that, at least initially, student epistemology becomes increasingly naïve as they commit themselves to a Science major.

The initial trend to increasingly naïve epistemological beliefs was reflected in the gender differences found in the present study. Specifically, female students who chose Science as a favorite and/or as a major had significantly stronger beliefs in learning (i.e., a fixed ability to learn) and knowledge (i.e., knowledge is simple, isolated facts) than did females who chose a subject other than Science as a favorite subject and/or a major. Female students did, in general, however, have lower endorsements of Fixed Ability and Quick Learning in relation to their male counterparts. The trend towards increased naïveté in epistemology, particularly with respect to conceptions of knowledge, may reflect the epistemological adoption of the strongly empiricist approach to Science pedagogical practice and the encyclopedic presentation of Science knowledge evident at the early undergraduate levels of university (Bendixen, Dunkle & Schraw, 1994).

The increase in the strength of naïve views of knowledge (e.g., knowledge as a compendium of isolated facts) is consistent with, and may reflect the adaptation to, the 'separate' approach to knowing reported by female Science majors in the current study (see Figure 3). The trend towards a 'separate' way of knowing and the changes in conceptions of knowledge, found in the present study, may reflect a more general process of aligning with the traditional demands of pedagogical practices in undergraduate Science courses; practices commonly described as empiricist in nature (Cary & Smith, 1993; Hammer, 1995). Although speculative, the implications of this alignment might range from fostering female student interest in graduate training (where there may be greater consistency between epistemology and discipline pedagogical practice) to mitigating further interest in, and commitment to, Science (if there is less alignment between epistemology and discipline pedagogical practices).

One process of mitigation may be a disconcordance between the epistemological demands of Science (i.e., as reflected in empiricist pedagogical practice and implied 'simple knowledge' conceptions of knowledge) and 'connected' approaches to knowing, which may be more consistent with viewing knowledge as constructed by or through individuals and bound by contexts and perspectives. This posited disconcordance has been previously noted (Belenky et al., 1986; 1997) but not in relation to a specific subject or to female persistence in Science. The present findings may suggest that, as a female student commits to a major in Science, there are shifts in the strength and relative importance of epistemological beliefs, which may or may not generate cognitive conflict, as well as a conflict arising from the adoption of a 'separate' way of knowing in both her academic and personal lives. These changes in epistemology, and the nature of their impact on female persistence in Science, are promising opportunities for further research.

Delimitations and Limitations of the Current Study

There were a number of circumstances that affected the findings in the present study. The following section discusses these circumstances in terms of research instruments and sample characteristics.

Research Instruments

Eccles' Scales. As previously noted in Chapter III (see Table 1), several of Eccles' scales in the present study had fair to good reliability (i.e., .71 to .86) and were thus consistent with the reliability values obtained by Eccles (Eccles, 1998, personal communication). However, several scales approached fair reliability (i.e., .68) and one scale (Utility: Job) obtained low reliability (i.e., .58), and these values were lower than those reported by Eccles. The range in reliability values (.58 to .86) indicated a need for caution when interpreting findings involving the scales with low to fair reliability.

In addition to the range in reliability values, several of Eccles' scales were composed of two items, Specifically: Utility: Courses, Self-Concept of Ability: Social Sciences, and Self-Concept of Ability: Advanced. Due to their size, two-item scales may not provide accurate internal reliability coefficients. Notwithstanding the preliminary nature of Eccles' scales, it is suggested that there is a need to further develop these scales.

Schommer's Epistemology Questionnaire. As noted in Chapter II, the literature discussing Schommer's (1990) Questionnaire indicates a range of statistical properties. For example, Schommer (1990) reported fair to good subscale reliabilities (i.e., .68 to .85) while several authors (e.g., Jehng, 1993) noted a lower range of reliability values (e.g., .42 to .59). Further, a recent review of the personal epistemology literature (Hofer and Pintrich, 1997) noted difficulties with item referents (i.e., a mix of first and third person referents across the scale). The results of the Cronbach alphas and Pearson correlations obtained in the current study appear to fall between those reported by Schommer (1990) and Jehng (1993). Specifically, in the present study, one subscale obtained fair reliability (Simple Knowledge, $r = .70$), two subscales obtained low reliability (Quick Learning, $r = .63$; Fixed Ability, $r = .64$), and one scale had poor reliability (Certain Knowledge, $r = .48$). This range in reliability values necessitated a cautious interpretation of findings involving those scales with low to poor reliability values. Further, the range of values may have negatively affected the strength of the significant correlations found between Schommer's (1990; 1994) and Eccles' (Eccles et al., 1983; Eccles 1987) models and, thus, deflated the variance accounted for by (and the practical import of) the correlations. Given the findings in the literature and the present study, it is suggested that Schommer's Questionnaire requires further development (e.g., revision of subscale items, additional factor analyses).

Sample Characteristics

The present study drew participants from three sources: two samples of undergraduate students drawn from large post-secondary institutions in Western Canada, and a sample of Shad Valley graduates currently attending post-secondary institutions across Canada. The latter sample, consisting of participants who excelled in Math and Science, was selected to provide a good opportunity to explore the research questions in the present study. The differences between the Shad Valley group and the remaining sample groups, in terms of GPA, was anticipated, given the nature of the group. However, there were several unanticipated differences. The parents of the Shad Valley group tended to have higher levels of education, and the Shad Valley sample contained a majority of the Science majors and students with a Science as a favorite subject (76% and 49%, respectively). In contrast, the university and college samples contained few Science majors (13% and 29%, respectively), and few students with a Science as a favorite subject (11% and 22%, respectively).

The differences in GPA and parent education, though of no known direct influence on the variables in the present study, indicate that some caution is warranted when generalizing beyond the three sample groups in the current study. As well, the distribution of Science majors and students with Science as a favorite subject further necessitates the need for caution when generalizing beyond the current study. This uneven distribution is the result of the unexpectedly low numbers of students with interests and involvement in Science, in both the university and college participant groups. These groups were intended to represent pools of general undergraduate students with a variety of academic interests. Unfortunately, both pools of participants held less than expected numbers of students with interests in Science. A review of the participants' academic years, programs, and institutions, across the three samples, indicated a consistent mix of undergraduate year (generally first through third year of undergraduate studies), type of institution the student was attending (e.g., college or university), and programs elected by students (e.g., Bachelor of Science, Bachelor of Arts, etc.).

Directions for Further Research

One area of further research suggested by the present findings is additional scale development. The reliability values of Schommer's (1990; 1994) Questionnaire obtained in the present study were consistent with the mixed findings in the Literature (see Chapter II for details). In both instances, several subscales did not reach satisfactory reliability. This suggests further work on Schommer's (1990; 1994) Questionnaire is needed. Such work might include an item review (i.e., face validity), addition of items, and a factor analysis of the questionnaire based on individual items rather than subsets of items. The addition of items is also necessary for several of Eccles' two-item scales (e.g., Utility: Courses, Self-Concept of Ability: Social Sciences).

The present study explored persistence in terms of student interests, defined as favorite subject, and student commitment to a major. Exploring the connections between these elements, and between these elements and student course selection, another element of persistence, in a longitudinal study would provide a richer description of persistence in a discipline.

An additional area of research suggested by the present findings is examining the shifts in the relative importance of Eccles' (Eccles et al., 1983; Eccles, 1987) task values (i.e., Attainment and Utility Values), evident when examining student interests and commitments to a discipline. Why do these shifts occur? What is their impact on persistence? How do these shifts relate to course selection?

A second area of research relating to Eccles' model is exploring the differences in the roles Expectations of Success, and Attainment and Utility values, play in course selection, student interests, and student commitment to a major. These constructs predict student course selection at the secondary level of education, do they predict course selection at the post-secondary level of education? If they do, why do these constructs fail to predict academic interests and commitments?

There are several areas of further research in epistemology that are suggested by the current findings. As previously noted, when contrasting student interests in and student commitments to a major, there are differences in the relative importance of various epistemological beliefs. How and why do these differences occur? What are the salient epistemological beliefs when selecting a course, and are these similar to those found for student interests in, and commitments to, a particular discipline?

There were several gender-related differences in epistemology that warrant further exploration. As previously noted, female students had a lower endorsement of Fixed Ability and Quick Learning than their male counterparts. Does a lower endorsement of these beliefs by female students act in some manner to mitigate persistence in Science, as Science appears to foster higher levels of beliefs in fixed ability? Do female students experience difficulty in shifting the direction of their epistemological positions (i.e., to a more naīve conception of knowledge and learning) and their approach to knowing (i.e., to a 'separate' way of knowing) in an effort to accommodate to the epistemological demands of the pedagogical practices in Science? Does the additive impact of these changes in the epistemology of female students discourage their persistence in Science?

Educational Implications

There are a number of practical implications arising from the findings in the present study. As noted above, undergraduate female students interested in, or committed to a major in, Science experienced changes in their conceptions of knowledge and learning, and in their approaches to knowing. In contrast, their male counterparts did not alter their epistemological beliefs or approaches to knowing. This gender-related pattern of epistemological change, and attending negative dissonance, represents a significant obstacle to pursuing an advanced education in the Sciences (Belenky et al., 1986; 1996; Hofer, 1994; Touchton et al., 1977). If we are to minimize the need for, and the negative impact of, epistemological change in female students, and thus foster their persistence in Science, it may be helpful to revisit pedagogical practice, in general, and in the undergraduate Science classroom.

A number of initiatives to change undergraduate pedagogical practice, across disciplines, have been drawn from Belenky et al.'s (1986) Women's Ways of Knowing (WWK). The authors of the WWK model of epistemology, and subsequent researchers, have explored its application in the areas of post-secondary and adult education (e.g., Clinchy, 1990; Clinchy, 1995; Carfagna, 1995; Enns, 1993; Lyons, 1990) in an effort to improve female participation in advanced education. They have reconsidered traditional curriculum and pedagogical practice as they developed and established Women's Studies programs in the U.S. (Carfagna, 1995; Musil, 1992). In addition, educators have drawn on the model and its ideas (e.g., 'connected' knowing, collaborative learning, and teacher as 'midwife') to promote greater understanding (i.e., knowledge of, and the personal relevance of, subject matter) in various disciplines (e.g., Clinchy, 1995; Trumball & Kerr, 1993).

The findings in the present study suggest that, when administrators and instructors attempt to promote greater understanding in a discipline, particularly in Science, by employing a pedagogy based on the WWK model, their efforts would benefit from expanding the focus on connected pedagogy (e.g., collaborative learning) to include addressing conceptions of knowledge and learning. Including these conceptions, and their role in Science, will better prepare female students for the changes in these beliefs (and attending dissonance) that occur as they commit to and pursue an advanced education in a Science.

With respect to Science pedagogy, there is an effort to move away from traditional pedagogical practice (and its implicit empiricist epistemology), and to adopt a 'constructivist' approach to Science (Carey & Smith, 1993; Edmonson & Novak, 1993; Nadeau & Desautels, 1984). The present findings suggest that female students, in particular, would benefit from this general change in Science pedagogy. Specifically, the central, active role of self in both 'constructivist' pedagogy and connected knowing (e.g., the personal construction, and thus increased relevance, of Science knowledge) may preempt the female students' need to accommodate a 'separate' approach to knowing, thus removing a source of dissonance that frequently mitigates persistence in a discipline (Belenky et al., 1986; Tobin, Tippins, & Hook, 1995).

In the present study, differences in epistemology were evident in first and second year undergraduate students. This suggests that any initiatives to address the gender differences in epistemology, as well as those relating to self-concept of ability, need to begin prior to entering a post-secondary institution (Schommer, 1993; Porath, 1996). One way of addressing these gender differences is to expand on the specialized high school counselling recommended by Masson and Hornby (1986). These authors have suggested that young female students need specialized approaches to career counselling, to make them aware of barriers (e.g., socialization, female education, and discrimination). The present findings suggest that, as part of the counseling on the barriers created by socialization and education, there needs to be counseling regarding the roles epistemology and epistemological dissonance play in their pursuit of an advanced education, particularly in the field of Science.

Summary and Conclusions

The current study explored factors underlying a well-documented and persistent tendency of female students to not pursue advanced courses and or careers in a Science, though they are as capable as male students in these disciplines. This question of persistence in Science was explored by defining two elements of persistence (i.e., student interests in Science and student commitment to a Science major) and examining, in relation to these elements, the relationships among Eccles' (Eccles et al., 1983; Eccles 1987) Model of Achievement Motivation, epistemological beliefs, and approaches to knowing.

The current study provides initial evidence of the applicability of Eccles' (Eccles et al., 1983; Eccles, 1987; 1994) model at the post-secondary level, a time of important decisions regarding careers in Math and Science. As well, the present findings suggest that beliefs about knowledge and learning (i.e., epistemological commitments) are directly associated with elements of persistence (e.g., committing to a major in a Science). In addition, there is a set of changes in epistemology experienced by female students and not by their male counterparts. The impact of these changes on female persistence in Science is an area needing further research.

In conclusion, female persistence in Science appears to be characterized by, in part, a dynamic set of relations involving constructs related to achievement motivation and epistemology. Further, the gender differences throughout this set of relationships indicate the gender-related pattern of persistence in Math and Science is a complex phenomenon, one requiring further study.

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APPENDIX A

A.1 Eccles' College Questionnaire

1. Are you in university?
   ____ Yes, part time
   ____ Yes, full time

2. Please estimate your parents' income level. If both parents work, combine their income.
   ____ less than $25,000 a year
   ____ 25,001 - 50,000 a year
   ____ 50,001 - 100,000 a year
   ____ more than 100,000 a year

3. Please indicate your parents' level of education.

Father		Mother	
____	less than high school	____	less than high school
____	high school	____	high school
____	training in a trade	____	training in a trade
____	undergraduate degree	____	undergraduate degree
____	graduate degree	____	graduate degree

4. Do you plan to get a Bachelor's degree?
   ____ Yes ____ No

   If yes, when do you expect to get it? Semester:__________ year:__________

5. People have different reasons for wanting to go to University. We would like to know why you want to go to university.

   Please use the following scale for the next set of questions.
   (WRITE A NUMBER ON THE LINE FOR EACH ITEM)

Strongly disagree					Strongly disagree	
1	2	3	4	5	6	7

I want to go to university because:

____ I might as well since there are no jobs available
____ My friends want me to go to university
____ I will be able to get a better job then if I didn't go to university
____ I will be able to get a certain kind of job that I can get only if I go to university
____ I will be able to meet a spouse/romantic partner
____ My parent(s) want me to go to university

____ I like being a student and learning new things
____ I can get a higher paying job
____ Most of my high school friends went to university
____ My romantic partner wants me to go to university
____ My friends are in university

6. What is your current Grade Point Average? ____________

7. What are your 2 favourite school subjects? _____________ and _____________

8. What are your 2 least favourite subjects? ______________ and ______________

A. YOUR MAJOR

9. Have you decided on a university major?

____ Yes ____ No (**If no**, SKIP TO QUESTION 17)

10. What is your university major? (If double, list both) __________________________

11. How much do you like taking courses in your major? (CIRCLE ONE)

Not at all						A lot
1	2	3	4	5	6	7

12. For me, being good at the course work for my major is

Not at all important						Very Important
1	2	3	4	5	6	7

13. How useful do you think your major is for the job you want to have in the future?

Not at all useful						Very useful
1	2	3	4	5	6	7

14. How good are you at the classes in your major?

Not at all good						Very good
1	2	3	4	5	6	7

15. Compared to most of your other courses, how good are you at courses in your major?

Much worse						Much better
1	2	3	4	5	6	7

PLEASE USE THE FOLLOWING SCALE TO ANSWER THE NEXT SET OF QUESTIONS.

Strongly disagree						Strongly agree
1	2	3	4	5	6	7

16. Why did you pick your current major? I picked my current major because....

____ I think I can make a lot of money in this area
____ The kind of jobs I can get in this area will allow me to be at home with my kids when I need to be
____ This is my area of interest
____ I am good at this area
____ Someone suggested this major to me.
____ It is an easy major
____ It is practical (I will gain skills that will help me get a job)
____ I like the kinds of jobs I can get with this major
____ People who are important to me have majored in this area
____ It is easier for people of my sex to get jobs in this area
____ I had a great class in this subject
____ A professor encouraged me to go into this field
____ It will allow me to continue into graduate or professional schools

17. Please list ALL majors you have considered.

______________ ______________ ______________ ______________

18. Do you have a favourite major?

No ____ Yes _____ .

If yes, what is it? ___________

19. Are you happy with your major?

No ____ Yes ____

Please explain why:

____

20. Rate how well you think you would do in each of the following university courses or programs
(PLEASE WRITE A NUMBER ON THE LINE FOR EACH ITEM)

I would not do well at all			I would do Average			I would do very well
1	2	3	4	5	6	7

____ Taking physical science or engineering courses
____ Taking life science or engineering courses
____ Taking literature or history or other humanities courses
____ Taking psychology, sociology or other social science courses
____ Taking math courses
____ In a master's degree program in the field you select for your major
____ In a master's degree program in the physical sciences or engineering
____ In a master's degree program in social sciences, social work, education, or similar program
____ In a master's degree program in business
____ In a Ph.D program in the field you select for your major
____ In medical school
____ In law school

21. How much university training would you like to get?
(CHECK ALL THAT APPLY)

_____ A bachelor's degree In what field? _____________
_____ A master's degree In what field?_____________
_____ An advanced degree What degree (e.g., Ph.D., law degree, an MD, etc.)? ______
In what field? _____________

22. How likely do you think it is that you will get a bachelor's degree (CIRCLE ONE)

Not at all likely						Very likely
1	2	3	4	5	6	7

23. How likely do you think it is that you will attend graduate school?

Not at all likely						Very likely
1	2	3	4	5	6	7

24. How likely do you think it is that you will get to earn the highest degree you would like to get?

Not at all likely — Very likely

1 2 3 4 5 6 7

25. **FOR THE NEXT SET OF QUESTIONS, USE THE FOLLOWING SCALE: (PLEASE WRITE A NUMBER ON THE LINE FOR EACH ITEM)**

Not at all true — Very true

1 2 3 4 5 6 7

____ I feel my courses are meaningful and important
____ My courses have influenced my career choice
____ Because of my school work, I see my spouse/romantic partner less often
____ Because of my school work, I see my other friends less often than I used to
____ I admire my professors
____ Faculty at my university helped make the transition to university pleasant for me
____ University staff helped make the transition to university pleasant for me
____ Other students helped make the transition to university pleasant for me
____ I have found it hard to make friends at university

26. How effective do you think you are in your university courses? (CIRCLE ONE)

Not at all Effective — Very effective

1 2 3 4 5 6 7

27. How effective do you think you are in your personal life at university?

Not at all effective — Very effective

1 2 3 4 5 6 7

28. How satisfied are you with the courses you have taken so far in university?

Not at all satisfied — Very satisfied

1 2 3 4 5 6 7

29. Do you feel like you have adjusted to university life?

Not at all well						Very well
1	2	3	4	5	6	7

30. Did you find going to university.....

Not at all stressful						Very stressful
1	2	3	4	5	6	7

B. UNIVERSITY AND FUTURE WORK

31. Are there any careers that you have ruled out because you do not like the math, physics, or chemistry classes that you would have to take?

_____ Yes _____ No

If yes, what are the careers you have ruled out?

32. How much time have you spent thinking about what kinds of things you need to do while in University in order to get the job you want to have when you are 40? (CIRCLE ONE)

No time At all						A lot of time
1	2	3	4	5	6	7

33. Have your future job plans affected the kinds of courses you are taking at university?

_______ Yes, a lot ________ Yes, a little ______ No (**if no**, go to the next question)

If yes, in what ways? (PLEASE LIST)

A.____

B.____

34. How helpful do you think the courses you have taken so far in university will be for the kind of job you want after you finish university?

Not at all helpful						Very helpful
1	2	3	4	5	6	7

35. How useful do you think the courses you have taken so far in university will be for your life after you finish university?

Not at all useful						Very useful
1	2	3	4	5	6	7

36. What is your work situation this summer? (CHECK ALL THAT APPLY)
____ Employed by others; part-time
____ Employed by others; full-time
____ Self-employed owner of own business or service, or professional practice

36. (CONT'D) What is your work situation this summer? (CHECK ALL THAT APPLY)

____ Temporarily laid off
____ Unemployed but looking for work
____ Unemployed but NOT looking for work
____ Working but not for pay

IF YOU ARE NOT CURRENTLY WORKING FOR PAY, GO TO QUESTION 41

37. How many hours per week do you work? ________________ hours per week

38. Do you think of this job as ..... (CHECK ONLY ONE)
_____ A long-term job
_____ as a step in your career
_____ a short-term job (a way to make money while you are at university)

39. Currently, what do you do in your job? (Please be specific, for example, if you are a secretary, also indicate the type of business; if you are in retail, indicate what you sell; if you work in child care, indicate the age group of the children you are responsible for, etc.)

____

____

40. How satisfied are you with your current employment? (CIRCLE ONE)

Not at all satisfied						Very satisfied
1	2	3	4	5	6	7

41. FOR THE NEXT SET OF QUESTIONS, USE THE FOLLOWING SCALE:
(PLEASE WRITE A NUMBER ON THE LINE FOR EACH ITEM)

Never						Daily
1	2	3	4	5	6	7

_____ I feel that my work is important and meaningful
_____ I learn things that will be useful to me later in life
_____ What I learn in school helps me do better on my job
_____ Because of my job, I have less time to do class assignments and school work
_____ I think about my job during class, so I miss what my professors are saying
_____ My job has influenced my career choice
_____ Being both a worker and a student is stressful
_____ Because of my job, I see my spouse/romantic partner less often than I used to
_____ Because of my job, I see my other friends less often than I used to
_____ I admire my work supervisor

42. How effective do you think you are in your job?

Not at all effective						Very effective
1	2	3	4	5	6	7

FOR THE NEXT SET OF QUESTIONS, PLEASE THINK ABOUT THE JOB YOU WORKED AT MOST DURING THE LAST SCHOOL YEAR

43. Did you have a job during the last school year?

______ Yes ______ NO (**If no**, go to question **46**)

44. How many hours per week did you work at that job? ________ hours per week

45. Did you think of that job as...... (CHECK ONLY ONE)
___ A long-term job ___ a short-term job (a way to make money while in university)
___ As a step in your career

46. What did you do in this job? (Please be specific, for example, if you are a secretary, also indicate the type of business; if you are in retail, indicate what you sell; if you work in child care, indicate the age group of the children you are responsible for, etc.)

____

____

47. FOR THE NEXT SET OF QUESTIONS, USE THE FOLLOWING SCALE:
(PLEASE WRITE A NUMBER ON THE LINE FOR EACH ITEM)

Never						Daily
1	2	3	4	5	6	7

_____ I feel that my work is important and meaningful
_____ I learn things that will be useful to me later in life
_____ What I learn in school helps me do better on my job
_____ Because of my job, I have less time to do class assignments and school work
_____ I think about my job during class, so I miss what my professors are saying
_____ My job has influenced my career choice
_____ Being both a worker and a student is stressful
_____ Because of my job, I see my spouse/romantic partner less often than I used to
_____ Because of my job, I see my other friends less often than I used to
_____ I admire my work supervisor
_____ I feel harassed at my job because of my sex

48. How satisfied were you with that job? (CIRCLE ONE)

Not at all satisfied					Very satisfied	
1	2	3	4	5	6	7

49. How effective did you think you were in that job?

Not at all effective					Very effective	
1	2	3	4	5	6	7

50. Do you plan to work during the next school year?
_____ Yes _____ No

If Yes, how many hours a week do you plan to work? _________________hours per week

APPENDIX A

A.2 Demographics

Study of Life Transitions: Supplement

1. **Are you a** ____ Male ______ Female

2. **What is your date of birth?** Month_____ Day_____ Year_____

3. **What is the highest level of formal education completed by your father? Your Mother? Your Partner?**

	Father	Mother	Partner
Some High school	1	2	3
Completed high school	1	2	3
Some college/CEGEP/Institute of Tech	1	2	3
Completed University degree in General Arts or Science	1	2	3
Don't know	1	2	3

4. **What is your partner's occupation, and what are (were) your father's and mother's principal occupations?** (Mark one in each column)

	Father	Mother	Partner
College or university teaching, research, or administration	1	2	3
Elementary or secondary school teaching or administration	1	2	3
Business owner	1	2	3
Other managerial or administrative	1	2	3
Technical and semi-professional	1	2	3
Other white collar, clerical, retail sales	1	2	3
Skilled wage worker	1	2	3
Semi- and unskilled wage worker, farm laborer	1	2	3
Armed forces	1	2	3
Home maker	1	2	3
Other (Please specify) ____________________________	_	_	_

APPENDIX A

A.3 Schommer's Epistemology Scale

Directions: There are no right or wrong answers for the following questions. We want to know what YOU really believe. For each statement circle the degree to which you agree or disagree.

01. If you are ever going to be able to understand something, it will make sense to you the first time you hear it.

Strongly Disagree				Strongly Agree
1	2	3	4	5

02. The only thing that is certain is uncertainty itself.

Strongly Disagree				Strongly Agree
1	2	3	4	5

03. A course in study skills would probably be valuable.

Strongly Disagree				Strongly Agree
1	2	3	4	5

04. The ability to learn is innate.

Strongly Disagree				Strongly Agree
1	2	3	4	5

05. It is annoying to listen to a lecturer who cannot seem to make up his mind as to what he really believes.

Strongly Disagree				Strongly Agree
1	2	3	4	5

06. Successful students understand things quickly.

Strongly Disagree				Strongly Agree
1	2	3	4	5

07. A good teacher's job is to keep his students from wandering from the right track.

Strongly Disagree				Strongly Agree
1	2	3	4	5

08. If scientists try hard enough, they can find the truth to almost anything.

Strongly Disagree				Strongly Agree
1	2	3	4	5

09. I try my best to combine information across chapters or even across classes.

Strongly Disagree				Strongly Agree
1	2	3	4	5

10. The most successful people have discovered how to improve their ability to learn.

Strongly Disagree				Strongly Agree
1	2	3	4	5

11. Things are simpler than most professors would have you believe.

Strongly Disagree				Strongly Agree
1	2	3	4	5

12. The most important aspect of scientific work is precise measurment and careful work.

Strongly Disagree				Strongly Agree
1	2	3	4	5

13. To me, studying means getting the big ideas from the text, rather than details.

Strongly Disagree				Strongly Agree
1	2	3	4	5

14. Educators should know by now which is the best method, lectures or small group discussions.

Strongly Disagree				Strongly Agree
1	2	3	4	5

15. Going over and over a difficult textbook chapter usually won't help you understand it.

Strongly Disagree Strongly Agree

1 2 3 4 5

16. Scientists can ultimately get to the truth.

Strongly Disagree Strongly Agree

1 2 3 4 5

17. You never know what a book means unless you know the intent of the author.

Strongly Disagree Strongly Agree

1 2 3 4 5

18. The most important part of scientific work is orginal thinking.

Strongly Disagree Strongly Agree

1 2 3 4 5

19. If I find the time to re-read a textbook chapter, I get a lot more out of it the second time.

Strongly Disagree Strongly Agree

1 2 3 4 5

20. Students have a lot of control over how much they can get out of a textbook.

Strongly Disagree Strongly Agree

1 2 3 4 5

21. Genius is 10% ability and 90% hard work.

Strongly Disagree Strongly Agree

1 2 3 4 5

22. I find it refreshing to think about issues that authorities can't agree on.

Strongly Disagree				Strongly Agree
1	2	3	4	5

23. Everyone needs to learn how to learn.

Strongly Disagree				Strongly Agree
1	2	3	4	5

24. A sentence has little meaning unless you know the situation in which it is spoken.

Strongly Disagree				Strongly Agree
1	2	3	4	5

25. Being a good student generally involves memorizing facts.

Strongly Disagree				Strongly Agree
1	2	3	4	5

26. Wisdom is not knowing the answers, but knowing how to find the answers.

Strongly Disagree				Strongly Agree
1	2	3	4	5

27. Most words have one clear meaning.

Strongly Disagree				Strongly Agree
1	2	3	4	5

28. Truth is unchanging.

Strongly Disagree				Strongly Agree
1	2	3	4	5

29. If a person forgot details, and yet was able to come up with new ideas from a text, I would think they were bright.

Strongly Disagree Strongly Agree

1 2 3 4 5

30. Learning definitions word-for-word is often necessary to do well on tests.

Strongly Disagree Strongly Agree

1 2 3 4 5

31. When I study, I look for the specific facts.

Strongly Disagree Strongly Agree

1 2 3 4 5

32. If a person can't understand something within a short amount of time, they should keep on trying.

Strongly Disagree Strongly Agree

1 2 3 4 5

33. If professors would stick more to the facts and do less theorizing, one could get more out of college.

Strongly Disagree Strongly Agree

1 2 3 4 5

34. I don't like movies that don't have an ending.

Strongly Disagree Strongly Agree

1 2 3 4 5

35. Getting ahead takes a lot of work.

Strongly Disagree Strongly Agree

1 2 3 4 5

36. It's a waste of time to work on problems which have no possibility of coming out with a clear-cut and unambiguous answer.

Strongly Disagree Strongly Agree

1 2 3 4 5

37. Some people aren born good learners, others are just stuck with limited ability.

Strongly Disagree Strongly Agree

1 2 3 4 5

38. Nothing is certain but death and taxes.

Strongly Disagree Strongly Agree

1 2 3 4 5

39. The really smart students don't have to work hard to do well in school.

Strongly Disagree Strongly Agree

1 2 3 4 5

40. Working hard on a difficult problem for an extended period of time only pays off for really smart students.

Strongly Disagree Strongly Agree

1 2 3 4 5

41. If a person tries too hard to understand a problem, they will most likely just end up being confused.

Strongly Disagree Strongly Agree

1 2 3 4 5

42. Almost all the information you can learn from a textbook you will get during the first reading.

Strongly Disagree Strongly Agree

1 2 3 4 5

43. Usually you can figure out difficult concepts if you eliminate all outside distractions and really concentrate.

Strongly Disagree Strongly Agree

1 2 3 4 5

44. A really good way to understand a textbook is to re-organize the information according to your own personal scheme.

Strongly Disagree Strongly Agree

1 2 3 4 5

45. Student who are 'average' in school will remain 'average' for the rest of their lives.

Strongly Disagree Strongly Agree

1 2 3 4 5

46. A tidy mind is an empty mind.

Strongly Disagree Strongly Agree

1 2 3 4 5

47. An expert is someone who has a special gift in some area.

Strongly Disagree Strongly Agree

1 2 3 4 5

48. I really appreciate instructors who organize their lectures meticulously and then stick to their plan.

Strongly Disagree Strongly Agree

1 2 3 4 5

49. The best thing about science courses is that most problems have only one right answer.

Strongly Disagree Strongly Agree

1 2 3 4 5

50. Learning is a slow process of building up knowledge.

Strongly Disagree Strongly Agree

1 2 3 4 5

51. Today's facts may be tomorrow's fiction.

Strongly Disagree Strongly Agree

1 2 3 4 5

52. Self-help books are not much help.

Strongly Disagree Strongly Agree

1 2 3 4 5

53. You will just get confused if you try to integrate new ideas in a textbook with knowledge you already have about a topic.

Strongly Disagree Strongly Agree

1 2 3 4 5

APPENDIX A

A.4 Schommer's Epistemology Scale (Revised)

Directions: There are no right or wrong answers for the following questions. We want To know what **you** really believe. For each statement circle the degree to which you agree or disagree.

01. If I am ever going to be able to understand something, it will make sense to me The first time I hear it.

Strongly Disagree				Strongly Agree
1	2	3	4	5

02. I believe that the only thing that is certain is uncertainty itself.

Strongly Disagree				Strongly Agree
1	2	3	4	5

03. I believe that a course in study skills would probably be valuable.

Strongly Disagree				Strongly Agree
1	2	3	4	5

04. I believe that the ability to learn is innate

Strongly Disagree				Strongly Agree
1	2	3	4	5

05. I find it annoying to listen to a lecturer who cannot seem to make up her/his mind as to what s/he really believes.

Strongly Disagree				Strongly Agree
1	2	3	4	5

06. I believe that I am beinga successful student when I understand things quickly.

Strongly Disagree				Strongly Agree
1	2	3	4	5

07. I believe a good teacher's job is to keep me focused on learning the knowledge in textbooks.

Strongly Disagree				Strongly Agree
1	2	3	4	5

08. I try my best to combine information across texts and even across classes.

Strongly Disagree				Strongly Agree
1	2	3	4	5

09. For me, part of being a successful student involves improving my ability to learn.

Strongly Disagree				Strongly Agree
1	2	3	4	5

10. I believe things are simpler than most professors would have you believe.

Strongly Disagree				Strongly Agree
1	2	3	4	5

11. I believe the most important aspect of scientific work is precise measurement and careful work.

Strongly Disagree				Strongly Agree
1	2	3	4	5

12. To me, studying means getting the big ideas from the text, rather than details.

Strongly Disagree				Strongly Agree
1	2	3	4	5

13. I believe educators should know by now which is the best method, lectures or small group discussions.

Strongly Disagree				Strongly Agree
1	2	3	4	5

14. I believe that going over and over a difficult textbook chapter usually won't help you understand it.

Strongly Disagree				Strongly Agree
1	2	3	4	5

15. I believe scientists can ultimately get to the truth.

Strongly Disagree				Strongly Agree
1	2	3	4	5

16. To understand what a book means, I need to know the intent of the author.

Strongly Disagree				Strongly Agree
1	2	3	4	5

17. I believe the most important part of scientific work is original thinking.

Strongly Disagree				Strongly Agree
1	2	3	4	5

18. If I take the time to re-read a textbook chapter, I get a lot more out of it the second time.

Strongly Disagree				Strongly Agree
1	2	3	4	5

19. I think I have a lot of control over how much I can get out of a textbook.

Strongly Disagree				Strongly Agree
1	2	3	4	5

20. I believe genius is 10% ability and 90% hard work.

Strongly Disagree				Strongly Agree
1	2	3	4	5

21. I find it challenging to think about issues that authorities can't agree on.

Strongly Disagree Strongly Agree

1 2 3 4 5

22. I believe everyone needs to learn how to learn.

Strongly Disagree Strongly Agree

1 2 3 4 5

23. I believe a sentence has little meaning unless I know the context in which it is presented..

Strongly Disagree Strongly Agree

1 2 3 4 5

24. For me, being a good student generally involves memorizing facts.

Strongly Disagree Strongly Agree

1 2 3 4 5

25. I believe wisdom is not so much knowing the answers, but knowing how to find the answers.

Strongly Disagree Strongly Agree

1 2 3 4 5

26. I believe most words have one clear meaning.

Strongly Disagree Strongly Agree

1 2 3 4 5

27. I believe truth is unchanging.

Strongly Disagree Strongly Agree

1 2 3 4 5

28. If a person typically forgot details, and yet was able to come up with new ideas from a text, I would think they were bright.

Strongly Disagree Strongly Agree

1 2 3 4 5

29. I believe learning definitions word-for-word is often necessary to do well on tests.

Strongly Disagree Strongly Agree

1 2 3 4 5

30. When I study, I look for the specific facts.

Strongly Disagree Strongly Agree

1 2 3 4 5

31. If I can't understand something within a short amount of time, I believe I should keep on trying.

Strongly Disagree Strongly Agree

1 2 3 4 5

32. I think that if professors would stick more to the facts and do less theorizing, I could get more out of college (or university).

Strongly Disagree Strongly Agree

1 2 3 4 5

33. I don't like movies that end in uncertainty.

Strongly Disagree Strongly Agree

1 2 3 4 5

34. I believe getting ahead takes a lot of work.

Strongly Disagree Strongly Agree

1 2 3 4 5

35. I believe it's a waste of time to work on problems which cannot yield a clear-cut and unambiguous answer.

Strongly Disagree Strongly Agree

1 2 3 4 5

36. I believe some people are born good learners, others are just stuck with limited ability.

Strongly Disagree Strongly Agree

1 2 3 4 5

37. I believe nothing is certain, except death and taxes.

Strongly Disagree Strongly Agree

1 2 3 4 5

38. I believe being really smart means not having to work hard to do well in school.

Strongly Disagree Strongly Agree

1 2 3 4 5

39. I believe that working hard on a difficult problem for an extended period of time only pays off for really smart students.

Strongly Disagree Strongly Agree

1 2 3 4 5

40. I think almost all the information I can learn from a textbook I will get during the first reading.

Strongly Disagree Strongly Agree

1 2 3 4 5

41. For me, a really good way to understand a textbook is to re-organize the information according to my own personal scheme (or outline).

Strongly Disagree Strongly Agree

1 2 3 4 5

42. I believe students who are "average" in school will remain "average" for the rest of their lives.

Strongly Disagree Strongly Agree

1 2 3 4 5

43. I believe a tidy mind is an empty mind.

Strongly Disagree Strongly Agree

1 2 3 4 5

44. I believe an expert is someone who has a special gift in some area.

Strongly Disagree Strongly Agree

1 2 3 4 5

45. I really appreciate instructors who organize their lectures meticulously and then stick to their plan.

Strongly Disagree Strongly Agree

1 2 3 4 5

46. I believe the best thing about science courses is that most problems have only one right answer.

Strongly Disagree Strongly Agree

1 2 3 4 5

47. I believe learning is a slow process of building up knowledge.

Strongly Disagree Strongly Agree

1 2 3 4 5

48. I believe today's facts may be tomorrow's fiction.

Strongly Disagree Strongly Agree

1 2 3 4 5

49. I believe self-help books can not be much help.

Strongly Disagree Strongly Agree

1 2 3 4 5

50. I believe I will just get confused if I try to integrate new ideas in a textbook with knowledge I already have about a topic.

Strongly Disagree Strongly Agree

1 2 3 4 5

APPENDIX A

A.5. Interview Questions

<u>Interview Script</u>

There are many differing views on the nature of science and scientific knowledge. I would like your views on the following four statements:

1 (cc). Scientific knowledge is a changing and evolving body of concepts and theories

Prompts: Can you expand on your answer for me?.
Can you give me an example of what you mean?
Can you give me a view of scientific knowledge that you think is wrong?

2 (tr). Scientific method will eventually let people learn the real truth about the natural world and how it works.

Prompts: Can you expand on your answer for me?
Can you give me an example of what you mean?
Can you give me a view that you think is wrong?

3 (cc). Theories and models are products of the human mind and may or may not accurately represent reality.

Prompts: Can you expand on your answer for me?
Can you give me an example of what you mean?
Can you give me a view that you think is wrong?

4 (tr). The ultimate goal of Science is to gather all the facts about natural phenomena

Prompts: Can you expand on your answer for me?
Can you give me an example of what you mean?
Can you give me a view that you think is wrong?

5 (WOK). "As soon as someone tells me about their point of view, I immediately start arguing in my head the opposite point of view. When someone is saying something, I can't help turning it upside down."

Tell me what you think about this: is it true for you? In academic settings? In personal settings? Can you think of an opposite or opposing approach in academic settings? In personal settings?

APPENDIX B

B.1 Invitational Letter

I am a graduate student in the Department of Educational Psychology at the University of Calgary, conducting research under the supervision of Dr. Judy Lupart, as part of the requirements towards a Ph.D degree. I am writing to provide information regarding my study, "Personal Epistemology and Achievement-related Choices," so that you can make an informed decision regarding your participation.

My study is part of the Lupart, Boberg, and Smyth research programme examining personal, social, and achievement-related influences on individuals' involvement in the sciences. The purpose of my study is to explore the relationships between an individual's beliefs about knowledge and learning (i.e., personal epistemology) and their choice of university major. As part of the study, you will be asked to spend approximately 30 minutes completing a questionnaire composed of items surveying both your beliefs about knowledge and learning and several values relating to your chosen major or preferred disciplines.

Confidentiality and anonymity will be safe-guarded at all times. The questionnaires will be coded, and any information which may identify an individual respondent will not be shared with any other individuals prior to or following data collection. Only group results will be reported in any published studies. Consent forms and questionnaires will be stored in a locked filing cabinet at the University of Calgary and destroyed two years after completion of the study.

Two copies of the consent form have been provided. Please return one signed copy with the questionnaire and retain the other copy for your records. You should be aware that even if you give your permission you are free to withdraw from the study at any time.

If you have any questions, please feel free to contact me at (403) 289-1814 (mess.), my supervisor Dr. Judy Lupart at 220-6280, the Office of the Chair, Faculty of Education Joint Ethics Review Committee at 220-5626, or the Office of the Vice-President (Research) at 220-3381.

Thank you for your time and cooperation

Sincerely,
Michael Enman

APPENDIX B

B.2 Participant Consent Form

I, the undersigned, hereby give my consent to participate in a research study exploring personal, social, and achievement-related influences on individuals' involvement in the sciences. Specifically, the relationships between beliefs about knowledge and learning and chosen (or preferred) major. This study is part of a 3 year research program funded jointly by the Social Sciences and Humanities Research Council of Canada and Northern Telecom, under the auspices of a Science and Culture Canada joint initiative.

I understand that such consent (indicated by marking the blanks below) means participating in the study.

_____ A Questionnaire set, completed in approximately 30 minutes, surveying personal epistemology (i.e., beliefs about knowledge and learning) and the subjective values assigned to a respondent's selected or preferred major.

I understand that participation in this study may be terminated at any time by my request or at the request of the investigator. Participation in this study and/or withdrawal form this study will not adversely affect me in any way.

I understand that my responses will be kept confidential and only group data will be reported in any published reports. Once collected, responses will be kept in strictest confidence in a locked file cabinet at the University of Calgary.

I have received a copy of this consent form for my records. I understand that if I have any questions I can contact the researcher, Michael Enman at (403) 289-1814, his supervisor, Dr. Judy Lupart at (403) 220-6280 or (403) 282-9244 (fax), the Office of the Chair, Faculty of Education Joint Ethics Review Committee at (403) 220-5626, or the Office of the Vice-President (Research) at (403) 220-3381.

______________ ______________________________

Date Signature

____

Participant's Printed Name

APPENDIX C

Definitions of Separate and Connected Ways of Knowing

The following definitions were drawn from Belenky, Clinchy, Goldberger, and Tarule (1986), and Goldberger, Tarule, Clinchy, and Belenky (1996).

Separate Way of Knowing

Separating oneself from an object through critical thinking and applying rules of exclusion to defend one's point of view and to eliminate other possibilities. The form of 'separate' knowing is argument and debate (versus narrative), and it starts from a 'doubting' position. The knower takes an independent, autonomous stance towards knowledge and knowing, and he/she challenges the other's knowledge and perspective by asking 'is it right?' rather than 'what does it mean?' Examples of this approach include critical thinking and the Scientific Method.

Connected Way of Knowing

Connecting oneself to the object by seeing self-other similarities, developing connections to many objects and points of view, and incorporating these into ones own knowing and knowledge. The form of 'connected' knowing is narrative (versus argument and debate), and it starts from a 'believing' position. The knower takes an empathetic, non-judgemental stance towards knowledge and knowing. A stance incorporating feelings, beliefs, convictions, and values. The individual asks 'what does it mean' rather than 'is it right.' The self is centrally involved in being able to think and know. Examples of this form of knowing include narrative thinking (drawing upon personal experiences and meanings).

APPENDIX D

Sample Characteristics by Group

		Shad Valley N=41	University N=55	College N=54	Sample Total N=148
Age		[1]22.4 (20-26)	19.4 (18-22)	21.0 (18-35)	20.8 (18-35)*
Gender	Female	[2]27 (65%)	27 (50%)	37 (58%)	89 (59%)*
	Male	14 (35%)	27 (50%)	19 (42%)	62 (41%)*
[3] Subject	Science	32 (78%)	13 (24%)	20 (36%)	65 (44%)**
	Nonscience	09 (22%)	40 (74%)**	34 (61%)**	83 (56%)**
[4]Major	Science	12 (30%)	07 (14%)	08 (14%)	27 (18%)**
	Nonscience	11 (27%)	13 (24%)	14 (25%)	38 (26%)**

[1] Mean age, within group; group range in brackets
[2] Number of subjects, within group; percentage, within group, provided in brackets
[3] Science as a favorite subject; a total of 148 participants indicated a favorite subject
[4] A total of 65 subjects (i.e., 44% of the sample of 148) declared a major; percentages in brackets (first three columns) reflect percentages of majors within group, the final column percentages refer to the overall sample N of 148
* Overall sample N equals 151
** Adjusted overall sample N equals 148, due to 3 incomplete male protocols (1 from the university sample and 2 from the college sample); the percentage in brackets refers to the adjusted, overall sample N of 148;